METEOROLOGICAL SITE SELECTION FOR

NUCLEAR POWER PLANTS

A THESIS

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METEOROLOGICAL SITE SELECTION FOR

NUCLEAR POWER PLANTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF ILLUSTRATIONS

SUMMARY

From a meteorological standpoint, the present procedure for choosing between two or more possible sites for nuclear power plants is of a qualitative nature. This thesis presents a quantitative approach using only the topography of the proposed site and nearby airport wind data. The results of the research indicate that the technique is valid and that two or more sites may therefore be ranked according to meteorological suitability.

CHAPTER I

INTRODUCTION

Statement of Problem

Choosing a site for a nuclear power plant requires the attention and skills of individuals from a number of engineering and scientific disciplines. Along with conventional siting criteria such as availability of land, water, labor supply and proximity to market, other factors must also be considered. These other factors are of an environmental nature and include, among others, the geology, seismology, hydrology, and meteorology of the proposed site. Each of these criteria must be considered in detail and a written report concerning them presented to the National Regulatory Commission (NRC) for approval.

Compared to other commercial power plants, nuclear plants impose unique requirements for safety precautions. This is due, in part, to the extreme toxicity of materials contained in the reactor core. During routine operation, small quantities of radionuclides are released to the atmosphere. The federal government has therefore placed stringent standards on gaseous effluents released from such plants. According to 10 CFR Part 20, Section 20.1(c) releases must be kept as low as practicable (ALAP) and Appendix 1 to 10 CFR

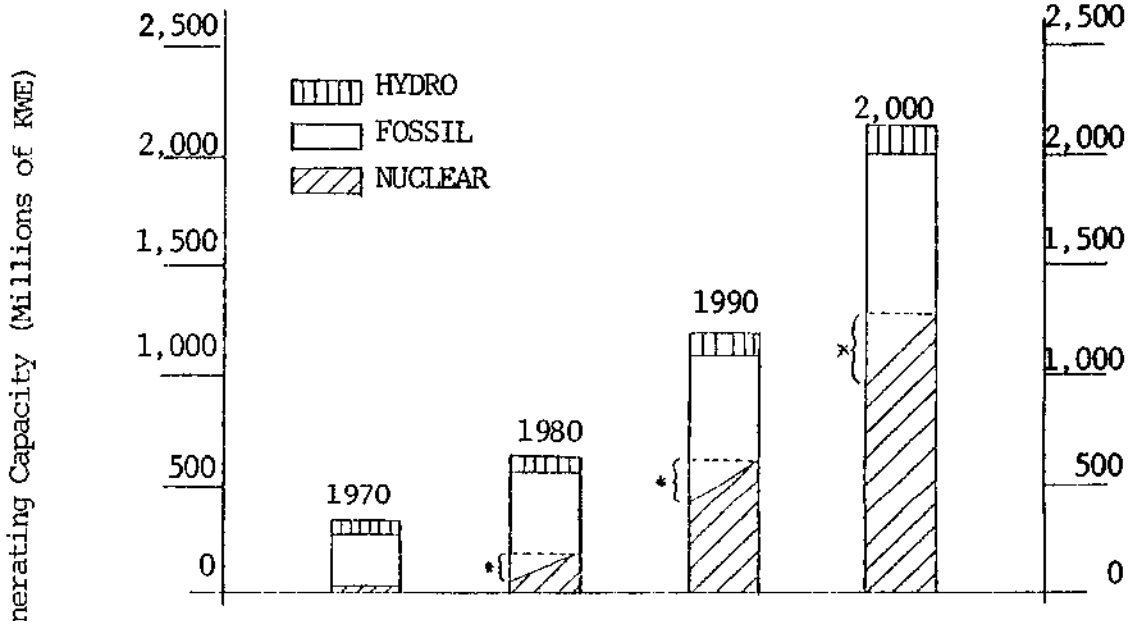
Part 50 provides numerical guidance for the effluents from light water cooled reactors. In addition, the power plant must meet the requirements of the Clean Air Amendments of 1970; however, due to the nature of nuclear plants this is not likely to be an important consideration. Although only gaseous effluents have been discussed here, there are also standards for liquid effluents and solid wastes.

Concerning accidental release of radioactive gases and particulates, federal government document 10 CFR Part 100 requires that an exclusion zone (EZ), low population zone (LPZ), and the distance to the nearest population center be defined for each nuclear plant. This is due to the fact that any radioactive effluents release ionizing radiation which can be deposited in human tissue. A measure of the amount of energy deposited is the rem. The document further states that the radiation dose to a person standing anywhere on the EZ boundary for two hours following a major accident should not exceed a whole body dose greater than 25 rem or a thyroid dose greater than 300 rem from iodine. In addition, a person standing anywhere on the outer edge of the LPZ should not receive a whole body dose greater than 25 rem or a thyroid dose greater than 300 rem from iodine during the entire passage of the radioactive cloud caused by the accident. The population center distance must be at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. These three factors are required in order that the radiation dose to the population surrounding the plant be kept at a minimum during a postulated credible accident.

The meterological characteristics of a site will determine, to some extent, the design and operating procedures for the proposed nuclear station. This is a logical consequence of the fact that meteorology is a function of nature and cannot be manipulated to any great degree. The plant design, however, can be modified and additional safety features installed to reduce emissions to ALAP. The plant can also be sited in an area with an acceptable EZ, LPZ, and population center distance.

Nuclear plants at present produce only a small fraction of the electric needs for the U. S. By the year 2000, it is estimated that nuclear plants will account for the bulk of electrical production in this country (Figure 1). Considering the state of technology and the limited sites available for their exploitation, solar energy, wind energy, geothermal, tidal, and even hydroelectric power are not capable of producing a large block of the U. S. power demand. The choice as to type of plant will then generally lie between fossil fuels (coal, oil, gas) and nuclear plants. Fossil fuel plants are having difficulty meeting air quality standards and are finding fuels more difficult and expensive to acquire. This will probably accelerate the trend toward use of nuclear power.

After a utility has determined a need for a new plant,



* Range of uncertainty in this projection

Figure 1. Projection of United States Electric Power Capacity

it is then faced with the problem of selecting a site which meets the general selection criteria. Generally, the company will know the approximate electrical capacity of their proposed plant and the region in which they wish to place it. They may also have as many as ten or more possible sites within the given region. From a strictly meteorological viewpoint, the problem would be to determine how each site ranks in comparison to the others.

Site Selection Considerations

In any region, the climatology will vary little from one section to another. There will be approximately the same amount of precipitation, number of tornadoes, storms, fogs, sunny days, and other such variables. These things are all considered when designing the plant. However, a climatological study does little in the way of aiding in the actual site selection. The plant location can only be chosen by comparing the particular characteristics of each site.

The present procedure for recommending the best site, meteorologically, is of a qualitative nature. It consists of first determining the climatology of the region, as mentioned, then of examining all available data for each proposed site. This data would generally consist of topographic maps and wind data from some nearby gathering station. The Holzworth (1972) mixing study would also be utilized in the initial process.

Factors Affecting Diffusion

The diffusion of effluents from the proposed nuclear plant will be dependent upon mean wind speed and direction, and the mechanical and thermal turbulence of the ambient atmosphere. The mean wind speed and direction will determine the rate and direction at which the effluents will travel to any receptors. Along with rate of travel, the wind speed will affect the concentration of effluent in the downwind direction. For a constant emission rate, a higher wind speed would indicate that more air passes by the source than at slower speeds. Therefore, the effluent is diluted into a larger volume of air.

Turbulence is an indicator of the variability of the wind from the mean values. There are velocity components in all directions having a random assortment of scales and periods. These deviations from the mean define turbulent eddies which affect any plant effluents in their vicinity. If the size of an eddy is larger than an effluent plume then the eddy will move the plume and thus contributes to the mean motion. If the eddy is smaller than the plume, then it will diffuse it and the eddy is therefore considered turbulent.

Mechanical turbulence is the induced eddy structure of the atmosphere due to the roughness of the surface over which the air is passing. Grass, trees, buildings, topographic features, and any other surface characteristics will cause mechanical turbulence. The height, spacing, and overall size of the roughness elements will affect the turbulence.

When the topography of the site is rough or hilly, the air passing over it will rise and fall in response to the surface undulations. This induces vertical turbulence. Since the air will also flow around some objects, horizontal turbulence is also generated. In either case, the mechanical turbulence will increase with wind speeds and decrease with height as the effect of the surface lessens.

Thermal turbulence is that induced by the stability of the atmosphere (see Appendix A for a discussion of stability). When the sun's radiation warms the earth's surface, the air near the surface becomes warm and rises. As this warm air rises the cooler air above it settles, only to be warmed and rise in turn. The atmosphere is said to then be unstable in this case. The intensity of thermal turbulence is greater on bright, sunny days with low wind speeds.

Atmospheric Dispersion Estimates

The stability of the atmosphere is an indicator of turbulence in general. The greater the turbulence the more an effluent is dispersed in the atmosphere. Pasquill (1961) derived some basic procedures to be used in making dispersion estimates. These were later modified by Gifford (1961). This technique is now recommended and used by the NRC and other regulatory agencies.

The procedure assumes any effluents are released either at ground level or from an elevated source into a normal x, y, z coordinate system. The x axis lies in the direction of the mean wind, the y axis lies perpendicular to the x and both lie in the horizontal plane. The z axis lies perpendicular to x and y and in the vertical plane. Figure 2 illustrates the coordinate system.

Equation 1.1 defines the concentration, χ, of gas or aerosols at a point in space x, y, z. The equation is representative of a continuous source with an effective emission height, H.

$$\chi(x,y,z;H) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\} \tag{1.1}$$

The term definitions and a consistent set of units are as follows:

χ =	the concentration of gas or aerosols at some point in space x,y,z	(gm/m^3) or ($curies/m^3$)
x,y,z =	coordinate system	(m)
H =	effective height of emissions; if effluents are released from a stack it is the sum of the physical stack height, h, and the plume rise, h′	(m)

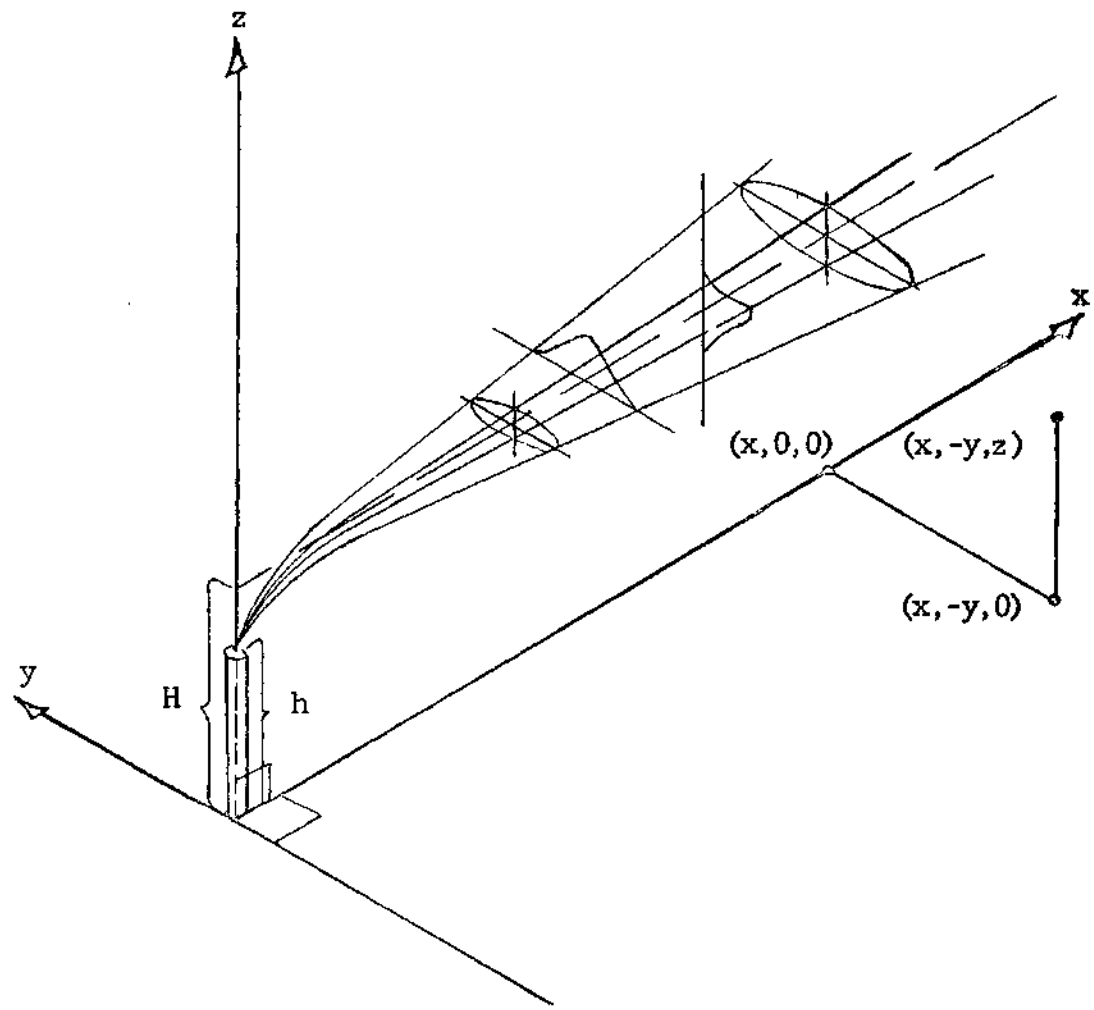


Figure 2. Coordinate System Used in Making Dispersion Estimates

Q = the emission rate of effluents (gm/sec) or (curies/sec)

σ_y = the horizontal standard deviation of plume concentration (m)

σ_z = the vertical standard deviation of plume concentration (m)

u = the mean wind speed at the height H (m/sec)

The equation requires that two basic assumptions be made before any application. These are: in both the horizontal and vertical planes the plume spread has a Gaussian distribution; total reflection of the plume occurs at the surface of the earth, i.e. there is no deposition or reaction at the surface. In using the equation, σ_y, and σ_z are evaluated at downwind distances corresponding to the value of x. Figures 3 and 4 depict the relationship between σ_y and x and σ_z and x respectively.

The equation, as written, may be used to estimate the dispersion of pollutants other than radioactivity. For nuclear plants, a main point of discharge of radioactive effluents is the turbine building roof where the building air is vented to the atmosphere. In this case, the effluent will be directly influenced by the aerodynamic flow patterns around the building. The building will thus alter downwind concentrations of radioactivity.

If it is assumed that the effluent is trapped in the downwind cavity caused by the building, then it will be rap-

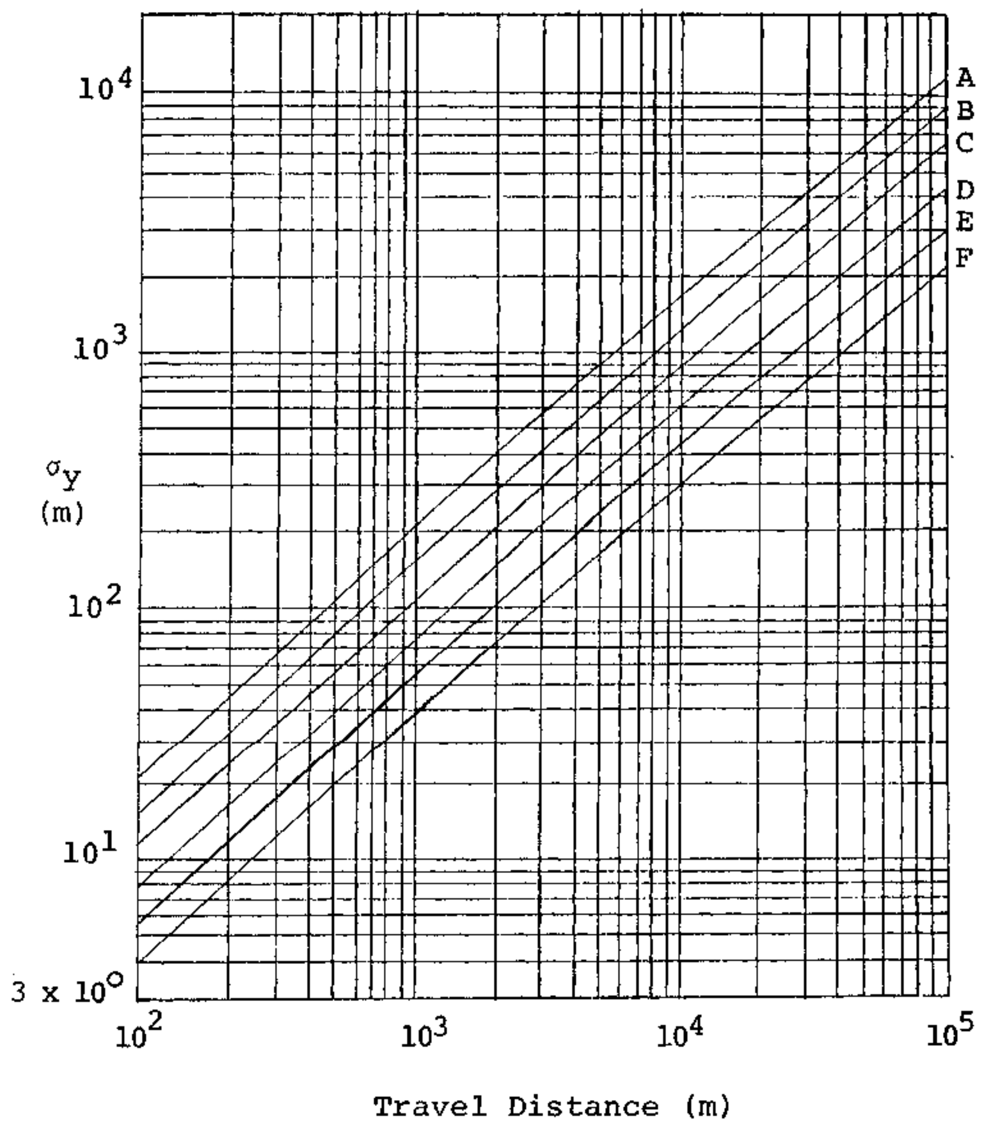


Figure 3. Standard Deviation of the Lateral Concentration Distributions

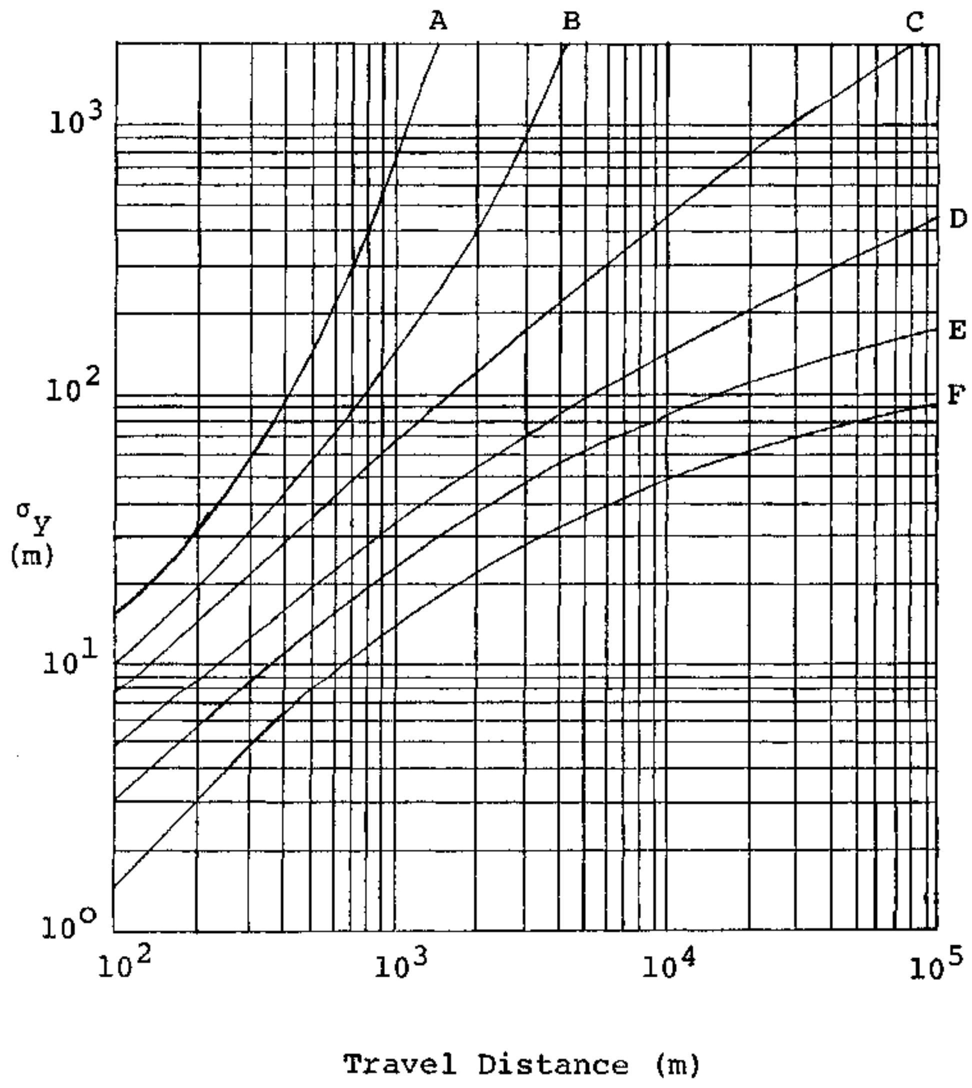


Figure 4. Standard Deviation of the Vertical Concentration Distribution

idly mixed within this cavity. The mixing volume will be roughly determined by the cross-sectional area of the building and the wind speed. This is an important consideration for nuclear plants as it will lower the concentration of any routine or accidental releases at the EZ and LPZ which are used as the x downwind distances. Since the concentration will be highest along the centerline of any plume, y can be set equal to o. H may also be set equal to o since there is no stack. Equation 1.1 now becomes

$$\chi(x,o,z;o) = \frac{Q}{u(\pi\sigma_y\sigma_z + cA)} \exp\left[-\frac{1}{2}\left(\frac{z}{\sigma_z}\right)^2\right] \qquad (1.2)$$

where

c = average turbine building shape factor ranging from 1/2 for a relatively streamlined shape to 2 for a less aerodynamic building.

A = cross-sectional area of the building normal to the wind (m^2)

and other terms are as defined previously.

While the dispersion estimates are not often utilized in ranking sites, they are used once a particular site is selected. Dispersion estimates for the site are calculated assuming a flat topography (i.e. z is defined as o) and centerline ground level concentrations with a building wake factor for short term releases. This will produce the maximum concentration at downwind distances and therefore a conservative estimate of concentration. The dispersion equation now becomes

$$\chi(x,o,o;o) = \frac{Q}{u(\pi\sigma_y\sigma_z + cA)} \tag{1.3}$$

If the wake factor is not known or χ is required at distances where cA is insignificant compared to the $\pi\sigma_y\sigma_z$ term, there is obtained

$$\chi(x,o,o;o) = \frac{Q}{u\pi\sigma_y\sigma_z} \tag{1.4}$$

It has become common practice for air pollution meteorologists to talk in terms of the ratio χ/Q. Equation 1.4 could then be considered as consisting of a plant term and a site term, respectively. The site term is dependent upon the site wind speed and distance to the evaluation point. The site term cannot be readily manipulated since it is dependent on nature. It may, therefore, be considered a characteristic of the site. For a given Q, the only way to bring χ to within the standards of 10 CFR 100 at the EZ and LPZ would be to extend the EZ and LPZ. The plant term, however can be manipulated. Q may be lowered by installing better safety features and generally improving the technology of the plant. Thus 10 CFR 100 could be satisfied and a minimum EZ and LPZ be defined.

The ratio χ/Q has meaning even if Q and cA are both unknown. By merely multiplying the site term by Q, the concentration at the site evaluation point may be computed. The site term can then be used in helping to design plan operating systems and procedures.

Purpose of Research

It is the purpose of this research to determine a simplistic, quantitative approach to the ranking of two or more possible nuclear sites. This would enable the individual responsible for recommending a particular site to be more confident of his selection. The best possible site would imply a minimum required EZ and LPZ. It would also provide information regarding the amount of engineering safeguards required.

Literature Review

As mentioned earlier, the present procedure for selecting nuclear sites can best be described as qualitative in nature. A review of pertinent literature has not disclosed any quantitative approaches. A number of guides, published by the federal government, provide insights as to required emission concentrations at downwind locations, equations for calculating these concentrations, and atmospheric conditions to assume for calculating the highest probable concentrations at these distances.

CHAPTER II

PROCEDURE

Approach to Problem Solution

As of December, 1972 a total of 30 nuclear plants were in operation, 59 were in various stages of construction, 78 were contracted for, and 19 had been announced as future additions to local capacities. Except for possibly some of the first nuclear plants, all of them have been required to file a Safety Analysis Report (SAR) and an Environmental Report (ER). Each SAR contains, along with other pertinent information, a detailed analysis of the on-site meteorology for the nuclear facility.

The meteorological analysis for a site must provide conservative and realistic estimates of atmospheric dilution at the site boundary (EZ) and the outer boundary of the LPZ. The calculations used to provide these estimates must include cumulative frequency distributions of hourly calculated atmospheric dilution factors (χ/Q) from onsite data using the minimum site boundary distance (EZ) and actual site boundary distances (EZ) from the effluent release point(s). The SAR must also list the χ/Q values from each of these cumulative distributions that are exceeded 5% and 50% (median value) of the time. Each authorized nuclear plant must file this information in its SAR.

The 5%χ/Q value may be considered a pertinent meteorological site characteristic since the probability that this dilution factor will not be exceeded in 95%. This number is derived by using equation 1.3 or a slight modification of it. The basic computational procedure consists of calculating a χ/Q value for each valid hour of onsite meteorological data for that sector and downwind distance specified which corresponds to the observed wind direction. χ/Q values for all other sectors are assumed to be zero. For the one hour release periods, all non-zero χ/Q values are ranked according to magnitude regardless of sector. The 5% value is then determined from this ranking.

Statistically, the 5%χ/Q value multiplied by the emission rate, represents that concentration which will be exceeded in only one observation in twenty at the EZ boundary. For a given Q, χ at the EZ boundary is totally dependent on the magnitude of the 5% value. Given a standard exclusion zone, two or more sites may be ranked on the basis of minimum 5%χ/Q values. The emission rate of a nuclear plant will, when that plant is in operation, affect the distance to the EZ boundary. However, it need not be considered when the only concern is the selection of the most appropriate site.

Before a SAR will be accepted, the NRC must ascertain, among other things, that the concentration of effluents at the EZ boundary will meet the criteria of 10 CFR 100. Of the plants in operation or under construction, it is known that the 5%χ/Q at the EZ will produce values of χ within the required standards, given the expected value of Q. It is, therefore, the intent of this thesis to derive a technique which will approximate the 5%χ/Q value for any site.

The technique will consist of the estimation of the 5%χ/Q values for six nuclear plants which have already filed a SAR. For purposes of clarity, the estimated χ/Q values will hereafter be referred to as E values. The E values will be derived using only the topography and nearest airport data for each of the six nuclear plants. From a correspondence between the 5%χ/Q values and the 5%E values, it may be concluded that the estimation procedure is valid. Also, the range of 5%χ/Q values for the six nuclear stations constitutes a range of valid 5%χ/Q values.

The same estimation technique may then be employed to calculate E values for any proposed nuclear sites. For computational purposes, it would be necessary to assume an EZ distance. This will directly affect the values of E. However, if at the assumed EZ distance, the value of the 5%E lies within the standard χ/Q range, the diffusion characteristics of the site will be known to be acceptable.

The topography and nearby airport data for any location are two easily and economically obtainable sets of information. Topography maps are obtainable from the office of the United States Geological Survey. Wind data, as collected at airports, military bases and other meteorological gathering stations, may be obtained from the National Oceanic and Atmospheric Administration Data Center located in Asheville, North Carolina.

The topography of an individual site can give an indication of air flow patterns and increased potential for high pollutant concentrations. Based on climatological considerations, local airport wind data should be representative of onsite winds, and therefore, valid for use in a first estimate. The use of onsite topography in conjunction with local wind data should force dispersion estimates to be representative of any particular site.

The 5%E value can be safely assumed to occur under either F or G stability and most likely G. These two stabilities are defined as stable and extremely stable, respectively, and both have characteristic low wind speeds. Any effluent released under these conditions will not disperse readily and therefore locally high concentrations of the effluent may be expected. For this reason, it is required that the frequency of occurrence of F and G stability classes be known. Appendix B discusses further details on obtaining the required wind data. It also describes a technique for extrapolating the required F and G frequencies when the frequencies of only A through E or A through F stability classes are known.

Procedural Details

The E values are calculated using equation 1.2. An EZ distance of one kilometer should be stipulated when comparing two or more sites. However, when calculating E for the six nuclear plants, the EZ distance defined in calculating the 5%χ/Q value was used. The value of cA for each plant was also used; for site selections cA may be defined as a constant equal to 1000 square meters.

Equation 1.2, modified for calculating E, becomes

$$E = \frac{1}{u(\pi\sigma_y\sigma_z + cA)} \exp\left[-\frac{1}{2}\left(\frac{z}{\sigma_z}\right)^2\right] \qquad (1.5)$$

where

E	=	estimated 5%χ/Q value	(curies/m^3)
u	=	annual average wind speed for each stability class independent of direction	(m/sec)
σ_y	=	the horizontal standard deviation of plume concentration; it is evaluated at 1 km for site selections	(m)
σ_z	=	the vertical standard deviation of plume concentration; it is evaluated at 1 km for site selections	(m)
c	=	building shape factor ranging from 1/2 for a relatively streamlined shape to 2 for a bluff building; the term cA is defined as 1000 m^2 when doing a site selection	
A	=	cross-sectional area of the building normal to the wind	(m^2)

and

z = the elevation of the topography at the evaluation point in relation to the elevation of the plant; z equals the elevation at the evaluation point minus elevation at the plant site (m)

E may be calculated using the included computer program Estimate (ESTMAT). A listing of the program and a sample input and output are contained in Appendix C. ESTMAT was written for use on the UNIVAV 1108 computer. It calculates E for each stability class at the EZ boundary for each of the 16 sectors surrounding the plant.

The first two cards are description cards. Each card may contain any 80 character message which will be printed as a heading on the output. The format for each header card is (20A4). The rest of the input is in NAMELIST format under the data set $INPUT. A description of the NAMELIST setup and use may be found in a computer systems manual. The following is a listing of the ESTMAT input and an explanation of the input variables:

ESTMAT Input

Two cards, with up to 80 characters each, to be used as run identifiers.

$INPUT

RELFRQ = x_1, x_2, x_3, x_4, x_5, x_6, x_7

relative frequency of occurrence of each stability class; they must be written as percentage and in the order A through G

WS = x_1, x_2, x_3, x_4, x_5, x_6, x_7

annual average wind speed for each stability class in knots

HT = x_1, x_2, through x_{16}

the topography elevations above mean sea level in meters at the EZ boundary for each of the 16 sectors; their order is clockwise with north as x_1

PHT = the plant elevation above mean sea level in meters

DIST = x_1, x_2, through x_{16}

the distances to the EZ boundary for each of the 16 sectors in meters; their order is clockwise with north as x_1; use 1000 m when doing site selections

CA = building wake factor; use 1000 m^2 when doing site selections

After ESTMAT has been run, the maximum value of E occurring under G stability is chosen. If the cumulative probability for G is not 5%, then it is necessary to plot, on log probability paper, the cumulative frequency of occurrence values for F and G stability against their respective E values. A straight line connecting these two points will cross the 5% probability line at the 5% value of E. This 5%E value is then an estimate of the 5%χ/Q value for that site.

For the six nuclear stations used in this report, both the 5%χ/Q and the 5%E values are available. By plotting the 5%χ/Q observed values against the 5%E estimated values, the 5%E values can be calibrated to the observed 5%χ/Q values. The points should be plotted on log-log graph paper and the "least-squares fit" of the points calculated. This will provide a best estimate of the 5%χ/Q for any site once the 5%E value for that site has been determined.

CHAPTER III

RESULTS AND DISCUSSION OF RESULTS

The 5%E values for the six nuclear power plants and for any proposed plant sites are calculated in an identical manner. This chapter will therefore base all results on computations made concerning these six power stations. A listing of the six and their abbreviations are presented in Table 1.

Tabular summaries of plant and site parameters peculiar to each station are shown in Tables 2 through 5. Further site statistics are included in Appendix D. Table 6 presents the maximum E values for the F and G stabilities. The F and G cumulative frequency values were derived from STAR output as discussed in Appendix B. Summaries of the pertinent facts for the computation of F and G are contained in Appendix D.

The values contained under the headings of "Cumulative Frequency" and "E" of Table 6 are plotted on log-probability graph paper in Figure 5. From this graph, the 5%E values which correspond to those of the 5%χ/Q values are obtained. Both quantities are listed in Table 7 for each station.

Figure 6 shows a plot of the 5%χ/Q and 5%E quantities. The straight line through the data points indicates the

Table 1. Nuclear Stations and Their Abbreviations

Nuclear Station	Abbreviation
Comanche Peak Steam Electric Station, Units 1 and 2	CPSES
River Bend Station, Units 1 and 2	RBS
Douglas Point Nuclear Generating Station	DPNGS
Greenwood Energy Center Units 2 and 3	GEC
Allens Creek Nuclear Generating Station, Units 1 and 2	ACNGS
Surry Power Station Units 3 and 4	SPS

Table 2. Parameters Pertaining to the Nuclear Plants

Nuclear Station	Distance To EZ (m)	cA, Building Wake Factor (m^2)	5% χ/Q (sec/m^3)
CPSES	variable	1110.0	2.3×10^{-4}
RBS	variable	692.0	2.5×10^{-3}
DPNGS	variable	1000.0	4.2×10^{-4}
GEC	1300.0	1000.0	2.48×10^{-4}
ACNGS	variable	1095.0	3.5×10^{-4}
SPS	503.0	645.0	7.9×10^{-4}

Table 3. Wind Speeds

Nuclear Station	Stability Class	Wind Speed (Knots)
CPSES	F	4.2
	G	1.5
RBS	F	4.2
	G	1.5
DPNGS	F	4.8
	G	1.9
GEC	F	4.2
	G	1.5
ACNGS	F	4.2
	G	1.5
SPS	F	4.2
	G	1.5

Table 4. EZ Distance and Elevation above Mean Sea Level at which 5%E Occurred for Each Station

Nuclear Station	EZ Distance (m)	Elevation (m)
CPSES	1417.5	248.90
RBS	526.0	29.40
DPNGS	1006.0	17.56
GEC	1300.0	229.00
ACNGS	1335.0	44.50
SPS	503.0	11.76

Table 5. Plant Elevations above Mean Sea Level

Nuclear Station	Elevation (m)
CPSES	246.9
RBS	29.0
DPNGS	16.7
GEC	229.0
ACNGS	44.9
SPS	12.2

Table 6. F and G Stability E Values for Each Station

Nuclear Station	Stability Class	Cumulative Frequency	E (sec/m^3)
CPSES	F	12.425	1.261×10^{-4}
	G	2.500	5.993×10^{-4}
RBS	F	18.700	3.919×10^{-4}
	G	5.900	1.456×10^{-3}
DPNGS	F	29.439	1.629×10^{-4}
	G	10.951	6.503×10^{-4}
GEC	F	13.587	1.436×10^{-4}
	G	2.900	6.847×10^{-4}
ACNGS	F	20.384	1.357×10^{-4}
	G	5.000	6.395×10^{-4}
SPS	F	10.300	4.214×10^{-4}
	G	1.930	1.564×10^{-3}

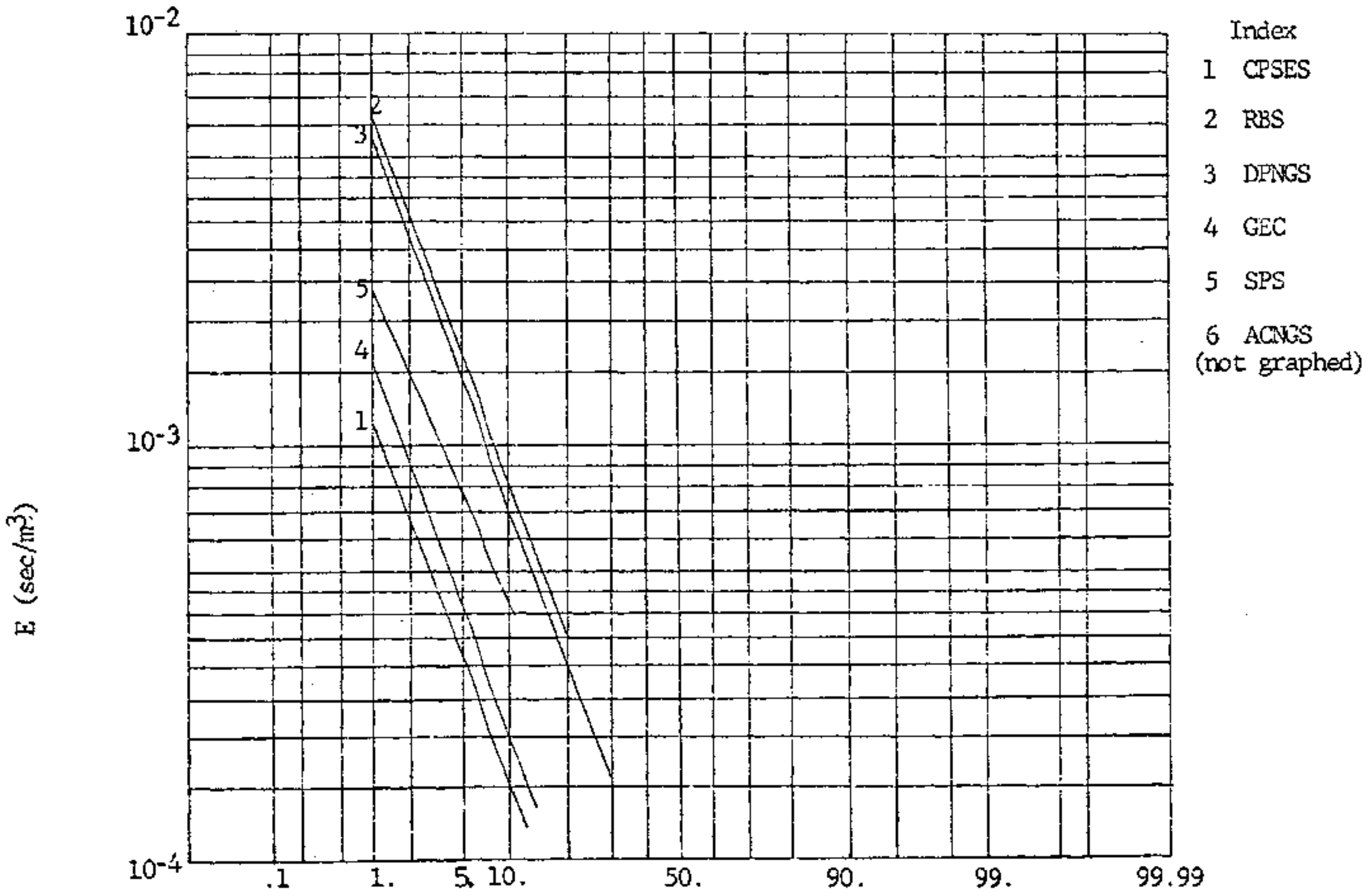


Figure 5. 5% E by Graphical Technique

Table 7. 5%E Values and Corresponding 5%X/Q Values

Nuclear Station	5%E (sec/m^3)	5%X/Q (sec/m^3)
CPSES	3.2×10^{-4}	2.3×10^{-4}
RBS	1.68×10^{-3}	2.509×10^{-3}
DPNGS	1.48×10^{-3}	4.2×10^{-4}
GEC	4.2×10^{-4}	2.48×10^{-4}
ACNGS	6.4×10^{-4}	3.5×10^{-4}
SPS	7.9×10^{-4}	7.9×10^{-4}

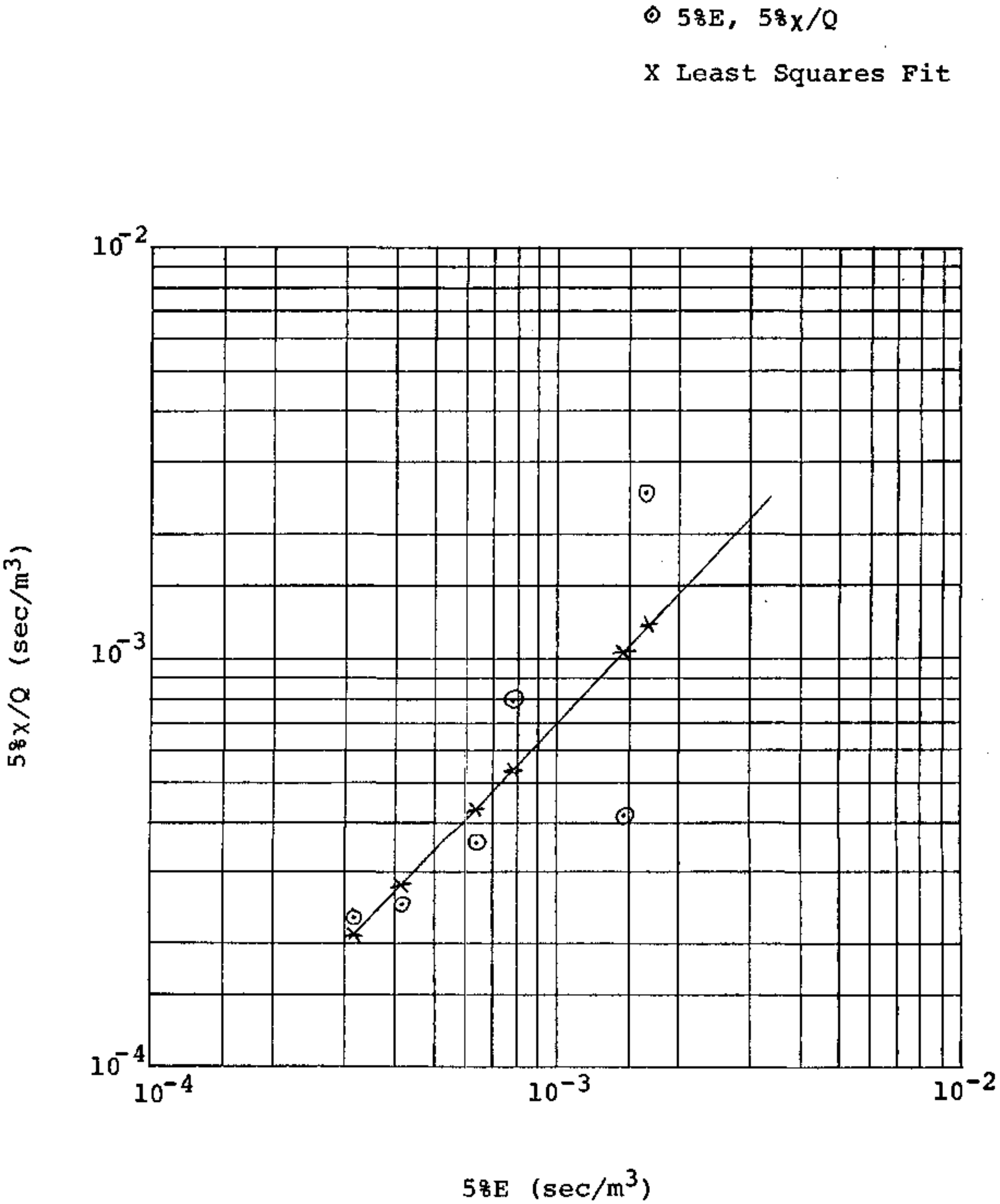


Figure 6. 5%χ/Q versus 5%E

"least squares fit." An estimate of the 5%χ/Q value for a site may be determined by computing the 5%E for the site and then referencing Figure 6.

CHAPTER IV

CONCLUSIONS

Based on data presented within this thesis, the following may be concluded:

1. An estimate of the 5%χ/Q value for a particular site may be determined from an analysis of only the local topography and meteorology of that site. The estimate is defined in this thesis as the 5%E value.

2. The meteorological suitability of two or more sites may be ranked either on the basis of the estimated 5%E value or the estimated 5%χ/Q value.

CHAPTER V

RECOMMENDATIONS

This thesis has presented a quantitative method for site comparisons. The one basic parameter on which each decision rests is the frequency of occurrence of the F and G stability classes. Due to economic considerations, it was not possible to purchase the seven stability frequency distributions for the airports near the six nuclear stations used in this research. It was, therefore, necessary to develop the technique discussed in Appendix B. There are two possible routes for improving the thesis results. These are:

1. Purchase the seven stability wind distributions for the local meteorological stations.

2. Derive a more accurate procedure for estimating the F and G frequency of occurrence.

Alternative two provides an interesting subject in itself. The determination of stability classes employing the technique utilized in the NOAA program STAR forces certain stability classes to occur or not to occur within specific wind speed intervals. The stability classes determined by use of the temperature difference or wind variability methods do not have this specific "interval" trait. As an example, using the NOAA technique, G stability can occur only between 0.0 and 3.5 miles per hour; using the temperature difference method G stability has occurred in one study at wind speeds as high as 18.0 miles per hour. A relevant study would then be to determine whether one stability classification approach forces the increase or decrease of the frequency of occurrence of one or more stability classes.

APPENDICES

APPENDIX A

STABILITY CATEGORIES

The standard method for defining the stability of the atmosphere is based upon the Pasquill class structure as listed in Table 8. For the purposes of this thesis, the stability of the atmosphere as determined in the National Ocenaic and Atmospheric Administration's (NOAA) computer program Stability Rose (STAR) will be discussed. This method utilizes hourly airport observations of wind speed, insolation, and other pertinent facts to determine atmospheric stability. The program outputs wind frequency distributions according to each stability class. A sample of the output for Norfolk, Virginia for A and B stability classes is presented in Tables 9 through 12.

A discussion of the technique employed by STAR and presented with each STAR output is given in its entirety on pages 45 through 48.

Table 8. Pasquill Stability Classes

Pasquill Stability Classification	Alternate Pasquill Classification	Definition
1	A	Extremely Unstable
2	B	Unstable
3	C	Slightly Unstable
4	D	Neutral
5	E	Slightly Stable
6	F	Stable
7	G	Extremely Stable

Table 9. Norfolk, Virginia, STAR Output

ANNUAL FREQUENCY DISTRIBUTION STATION #13750 NORFOLK,VA/NAS 12/64-11/71

SPEED(KTS)

DIRECTION	1 - 3	4 - 6	7 - 10	11-16	17-21	GREATER THAN 21	AVG SPD	TOTAL
N	24	37	0	0	0	0	3.6	61
NNE	12	32	0	0	0	0	3.8	44
NE	7	21	0	0	0	0	3.9	28
ENE	7	18	0	0	0	0	4.0	25
E	12	12	0	0	0	0	3.3	24
ESE	1	1	0	0	0	0	3.5	2
SE	1	1	0	0	0	0	3.5	2
SSE	1	4	0	0	0	0	4.0	5
S	7	3	0	0	0	0	2.6	10
SSW	7	8	0	0	0	0	3.6	15
SW	3	18	0	0	0	0	4.2	21
WSW	6	24	0	0	0	0	4.1	30
W	14	26	0	0	0	0	3.7	40
WNW	4	6	0	0	0	0	3.3	10
NW	2	4	0	0	0	0	3.8	6
NNW	5	7	0	0	0	0	3.4	12
AVG	2.3	4.4	0.0	0.0	0.0	0.0	3.1	
TOTAL	113	222	0	0	0	0		

NUMBER OF OCCURRENCES OF A STABILITY = 402

NUMBER OF CALMS WITH A STABILITY = 67

Table 10. Norfolk, Virginia, STAR Output

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =13750 NORFOLK,VA/NAS 12/66-11/71

SPEED(KTS)

DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000827	0.000845	0.000000	0.000000	0.000000	0.000000	0.001671
NNE	0.000475	0.000731	0.000000	0.000000	0.000000	0.000000	0.001206
NE	0.000288	0.000479	0.000000	0.000000	0.000000	0.000000	0.000767
ENE	0.000274	0.000411	0.000000	0.000000	0.000000	0.000000	0.000685
E	0.000384	0.000274	0.000000	0.000000	0.000000	0.000000	0.000658
ESE	0.000032	0.000023	0.000000	0.000000	0.000000	0.000000	0.000055
SE	0.000032	0.000023	0.000000	0.000000	0.000000	0.000000	0.000055
SSE	0.000046	0.000091	0.000000	0.000000	0.000000	0.000000	0.000137
S	0.000205	0.000068	0.000000	0.000000	0.000000	0.000000	0.000274
SSW	0.000228	0.000183	0.000000	0.000000	0.000000	0.000000	0.000411
SW	0.000164	0.000411	0.000000	0.000000	0.000000	0.000000	0.000575
WSW	0.000274	0.000548	0.000000	0.000000	0.000000	0.000000	0.000822
W	0.000502	0.000594	0.000000	0.000000	0.000000	0.000000	0.001096
WNW	0.000137	0.000137	0.000000	0.000000	0.000000	0.000000	0.000274
NW	0.000073	0.000091	0.000000	0.000000	0.000000	0.000000	0.000164
NNW	0.000169	0.000160	0.000000	0.000000	0.000000	0.000000	0.000329
TOTAL	0.004110	0.005069	0.000000	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF A STABILITY = 0.009179

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH A STABILITY = 0.001530

Table 11. Norfolk, Virginia, STAR Output

ANNUAL FREQUENCY DISTRIBUTION STATION #13750 NORFOLK,VA/NAS 12/66-11/71

	SPEED(KTS)							
DIRECTION	1 - 3	4 - 6	7 - 10	11-16	17-21	GREATER THAN 21	AVG SPD	TOTAL
N	101	212	62	0	0	0	4.7	375
NNE	43	162	98	0	0	0	5.6	303
NE	36	101	52	0	0	0	5.5	189
ENE	31	152	120	0	0	0	5.9	303
E	58	92	64	0	0	0	5.2	214
ESE	28	26	6	0	0	0	4.1	60
SE	18	16	11	0	0	0	4.5	45
SSE	19	33	11	0	0	0	4.7	63
S	53	54	28	0	0	0	4.6	135
SSW	43	95	46	0	0	0	5.3	184
SW	40	56	41	0	0	0	5.1	137
WSW	55	111	70	0	0	0	5.3	236
W	62	159	81	0	0	0	5.4	302
WNW	14	31	19	0	0	0	5.2	64
NW	15	8	6	0	0	0	4.3	29
NNW	39	49	14	0	0	0	4.2	102
AVG	2.4	5.3	7.5	0.0	0.0	0.0	4.9	
TOTAL	655	1357	729	0	0	0		

NUMBER OF OCCURRENCES OF B STABILITY = 2876

NUMBER OF CALMS WITH B STABILITY = 135

Table 12. Norfolk, Virginia, STAR Output

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION #13750 NORFOLK,VA/NAS 12/66-11/71

SPEED(KTS)

DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.002786	0.004840	0.001416	0.000000	0.000000	0.000000	0.009042
NNE	0.001296	0.003699	0.002238	0.000000	0.000000	0.000000	0.007232
NE	0.001032	0.002306	0.001187	0.000000	0.000000	0.000000	0.004525
ENE	0.000988	0.003470	0.002740	0.000000	0.000000	0.000000	0.007198
E	0.001554	0.002101	0.001461	0.000000	0.000000	0.000000	0.005116
ESE	0.000722	0.000594	0.000137	0.000000	0.000000	0.000000	0.001453
SE	0.000463	0.000365	0.000251	0.000000	0.000000	0.000000	0.001080
SSE	0.000513	0.000753	0.000251	0.000000	0.000000	0.000000	0.001518
S	0.001374	0.001233	0.000639	0.000000	0.000000	0.000000	0.003246
SSW	0.001193	0.002169	0.001050	0.000000	0.000000	0.000000	0.004413
SW	0.001060	0.001279	0.000936	0.000000	0.000000	0.000000	0.003275
WSW	0.001510	0.002534	0.001598	0.000000	0.000000	0.000000	0.005643
W	0.001754	0.003630	0.001849	0.000000	0.000000	0.000000	0.007234
WNW	0.000389	0.000708	0.000434	0.000000	0.000000	0.000000	0.001530
NW	0.000378	0.000183	0.000137	0.000000	0.000000	0.000000	0.000697
NNW	0.001025	0.001119	0.000320	0.000000	0.000000	0.000000	0.002464
TOTAL	0.018037	0.030983	0.016645	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF B STABILITY = 0.065665

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH B STABILITY = 0.003082

The following explanation of the Pasquill Stability classification has been extracted from an article by D. Bruce Turner in the Journal of Applied Meteorology (1964)

This system of classifying stability on an hourly basis for research in air pollution is based upon work accomplished by Dr. F. Pasquill (1961) of the British Meteorological Office. Stability near the ground is dependent primarily upon net radiation and wind speed. Without the influence of clouds, insolation (incoming radiation) during the day is dependent upon solar altitude, which is a function of time of day and time of year. When clouds exist, their cover and thickness decrease incoming and outgoing radiation. In this system insolation is estimated by solar altitude and modified for existing conditions of total cloud cover and cloud ceiling height. At night estimates of outgoing radiation are made by considering cloud cover. This stability classification system has been made completely objective so that an electronic computer can be used to compute stability classes. The stability classes are as follows: 1) Extremely unstable, 2) Unstable, 3) Slightly unstable, 4) Neutral, 5) Slightly stable, 6) Stable 7) Extremely stable. Table 13 gives the stability class as a function of wind speed and net radiation. The net radiation index ranges from 4, highest positive net radiation (directed toward the ground), to -2 highest negative net radiation (directed away from the earth). Instability occurs with high positive net radiation and low wind speed; stability occurs with high negative net radiation and light winds; neutral conditions occur with cloudy skies or high wind speeds.

The net radiation index used with wind speed to obtain stability class is determined by the following procedures:

1) If the total cloud cover is 10/10 and the ceiling is less than 7000 feet, use net radiation index equal to 0 (whether day or night).
2) For night-time (night is defined as the period from one hour before sunset to one hour after sunrise):
    a) If total cloud cover $\leq$ 4/10, use net radiation index equal to -2.
    b) If total cloud cover $>$ 4/10, use net radiation index equal to -1.

Table 13. Stability Class as a Function of Net Radiation and Wind Speed

Wind Speed (Knots)	Net Radiation Index 4	3	2	1	0	-1	-2
0,1	1	1	2	3	4	6	7
2,3	1	2	2	3	4	6	7
4,5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8,9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
$\geq$12	3	4	4	4	4	4	4

3) For daytime:
   a) Determine the insolation class number as a function of solar altitude from Table 14.
   b) If total cloud cover $\leq$ 5/10, use the net radiation index in Table 13 corresponding to the insolation class number.
   c) If cloud cover > 5/10, modify the insolation class number by following these six steps:
      1) Ceiling < 7000 ft., subtract 2
      2) Ceiling $\geq$ 7000 ft., but < 16,000 ft., subtract 1
      3) Total cloud cover equal 10/10, subtract 1. (This will only apply to ceiling $\geq$ 7000 ft. since cases with 10/10 coverage below 7000 ft are considered in item 1 above).
      4) If insolation class number has not been modified by steps (1), (2), or (3) above, assume modified class number equal to insolation class number
      5) If modified insolation class number is less than 1, let it equal 1.
      6) Use the net radiation index in Table 13 corresponding to the modified insolation class number.

Since urban areas do not become as stable in the lower layers as non-urban areas, stability classes 5, 6, and 7 computed using the STAR program may be combined into a single class (5), or classes 6 and 7 may be combined and identified as class 6.

Table 14. Insolation as a Function of Solar Altitude

Solar Altitude (a)	Insolation	Insolation Class Number
$60^\circ < a$	Strong	4
$35^\circ < a \leq 60^\circ$	Moderate	3
$15^\circ < a \leq 35^\circ$	Slight	2
$a \leq 15^\circ$	Weak	1

APPENDIX B

WIND DATA INFORMATION

It is possible to obtain from the U. S. Department of Commerce, National Oceanic and Atmospheric Administration Data Center, located in Asheville, North Carolina, a wind distribution by Pasquill stability class. Their computer program, STAR, is capable of processing wind data into monthly, seasonal, annual, day-night, or other special hourly groupings. Meteorological data from all first-order weather stations, military bases, airports, and other data gathering stations are processed at this center.

The surface (anemometer height approximately 20 feet) wind distributions for a number of cities, military bases, and other sites have already been processed on STAR. A list of these stations, including pertinent information such as number of stability classes calculated and time periods may be obtained at no charge by requesting it through the center. However, the cost is rather high to obtain a wind distribution for a station which has not been run. The costs as shown in Table 15 vary depending on the number of years required and the time period. Four to six weeks are required between first ordering a particular distribution to be run and final receipt of it. Copies of previously run stations

Table 15. Costs For STAR Output Tables

First time a station is run on STAR

Annual Time Period (Yrs)	Five, Six, or Seven Stability Cost (For either 8 or 24 obs/day)
1	$ 60.00
5	$115.00
10	$150.00
Monthly & Annual (Yrs)	**Cost**
1	$ 90.00
5	$150.00
10	$200.00
Seasonal & Annual (Yrs)	**Cost**
1	$ 70.00
5	$125.00
10	$165.00

*Note: Copies of previously processed data may be obtained at a base cost of $8.00 per five stability distribution. Additional stabilities may be obtained at a cost of $1.00/page. For example, a five class annual stability would cost $8.00, a six class $10.00, and a seven class $12.00.

may be obtained at substantial savings. The rates for these are included in Table 15. For previously run stations, approximately two weeks are required from initial request until receipt of the desired copy (1975).

Most of the stations already processed through STAR have either five or six classes. This is probably due to the fact that the outputs are used for studies of the urban environment. Urban areas do not become as stable in the lower layers as non-urban areas. Stability classes five, six, and seven, may then be combined into a single class five or six and seven may be combined and identified as six.

Sometime it is necessary to have a seven stability distribution for a particular station. Such an instance would be in the derivation of the 5%χ/Q value. In this case, the wind distributions for the F and G stabilities are required since they represent the most stable conditions and therefore the stabilities under which the 5%χ/Q value is most likely to occur.

For nuclear power plants, the actual on-site wind distribution must eventually be obtained. However, in most instances, the seven stability distribution from a nearby meteorological station is used for a first estimate. If time or money are limited, it may be necessary to obtain an already existing five or six stability wind distribution from Asheville. This distribution could then be used to predict the full seven stability wind distribution.

Extrapolation Technique

A method of extrapolating a seven stability distribution from a five stability distribution has been derived. The seven stability annual distributions for Tampa, Tallahassee, and Orlando, Florida have been utilized as a basis for proof of the validity of the technique.

Initially the cumulative frequency of occurrence from G to A (Table 16) was plotted against stability on probability paper. The values are noted by the dots in Figures 7 through 9 for Tampa, Tallahassee, and Orlando, respectively. If only a five stability distribution were assumed for the three sites, then the only cumulative frequency values to be plotted would be for the points E through A. An imaginary "least squares" line passing through the points B, C, and D would miss the E point by approximately one-half stability unit. This is due to the strong influence of the D or neutral stability in the cumulative frequency. Table 17 shows that D stability for the three locations has the largest frequency of occurrence. By next assuming that the cumulative frequency values of E, F, and G must lie on this imaginary "least squares" line, then their frequency of occurrence can be determined by raising their stability values by one-half stability unit in each case. The ER, FR, and GR values noted in the figures represent the extrapolated values for E, F, and G.

A "least squares" technique was used to produce the line B, C, D, ER. With this technique, the line is forced

Table 16. Cumulative Frequency of Occurrence of Stabilities G through A In Percent

Tampa		Tallahassee	
Stability	Cumulative	Stability	Cumulative
G	1.2101	G	8.8699
F	11.7149	F	23.3882
E	31.6971	E	38.1348
D	82.9608	D	78.6691
C	95.6894	C	91.2399
B	99.6507	B	98.7490
A	100.0000	A	100.0001

Orlando	
Stability	Cumulative
G	4.8105
F	21.3470
E	39.9018
D	79.7717
C	92.9977
B	99.0616
A	100.0000

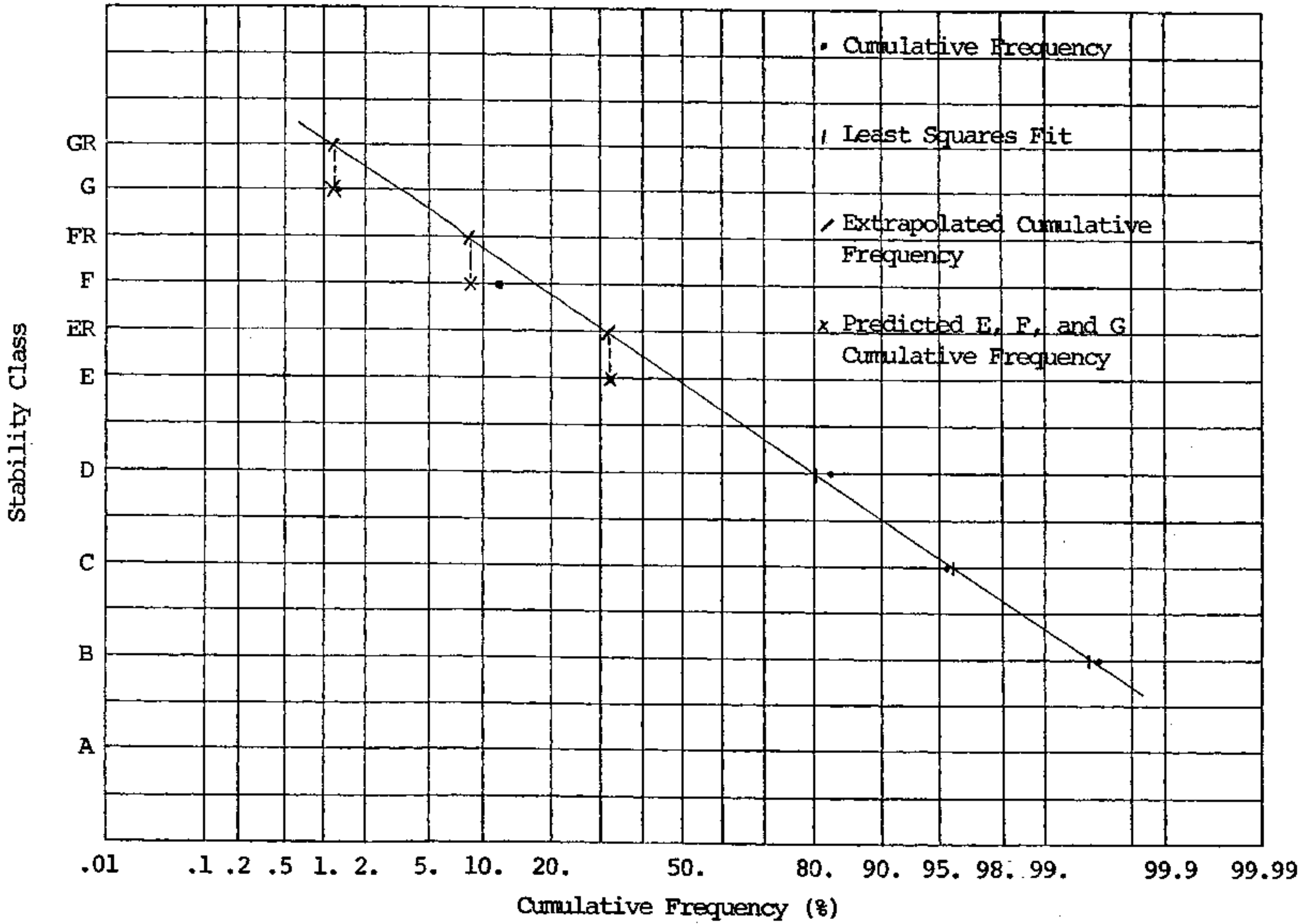


Figure 7. Tampa Cumulative Frequency of Occurrence (G to A).

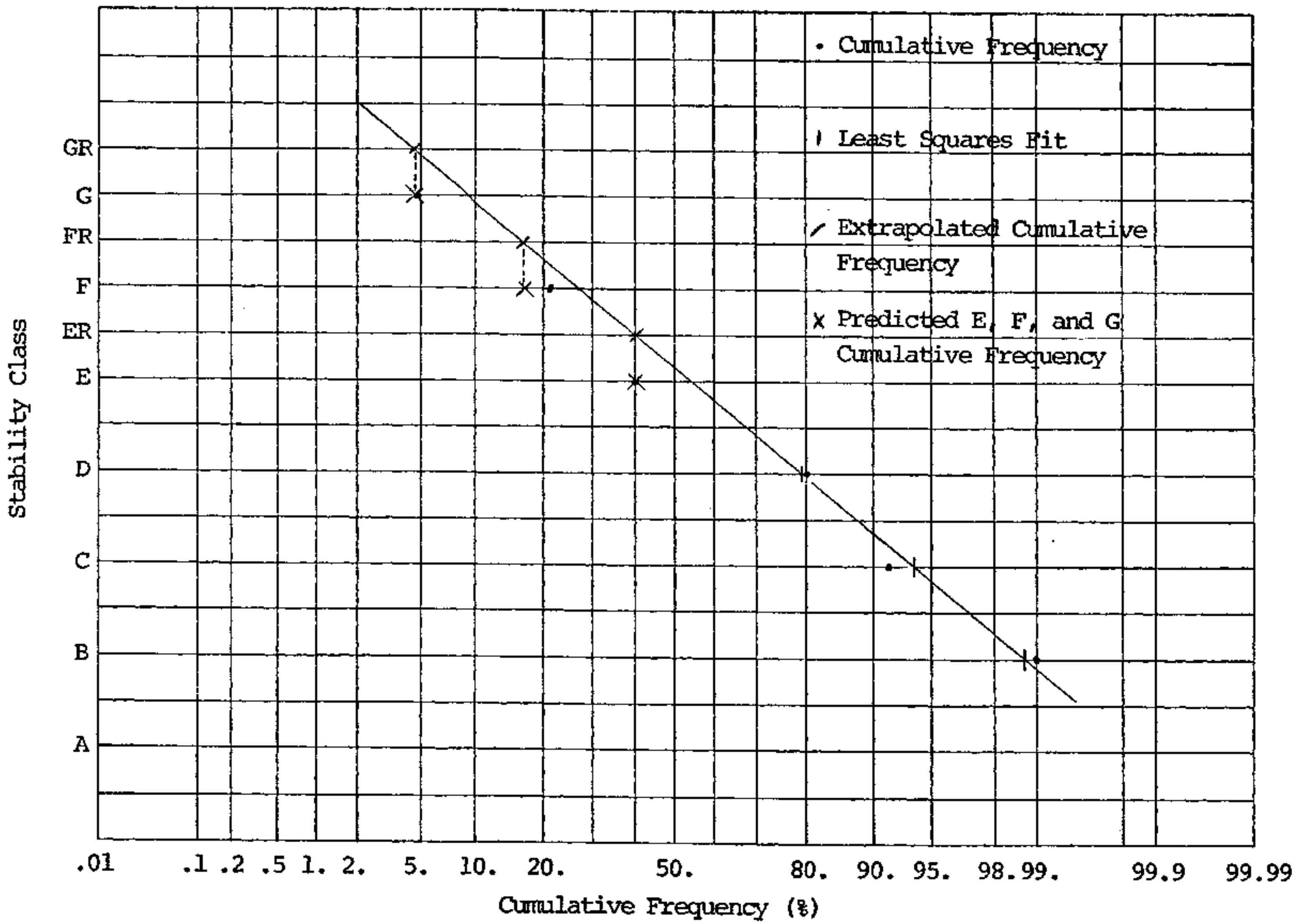


Figure 8. Tallahassee Cumulative Frequency of Occurrence (G to A).

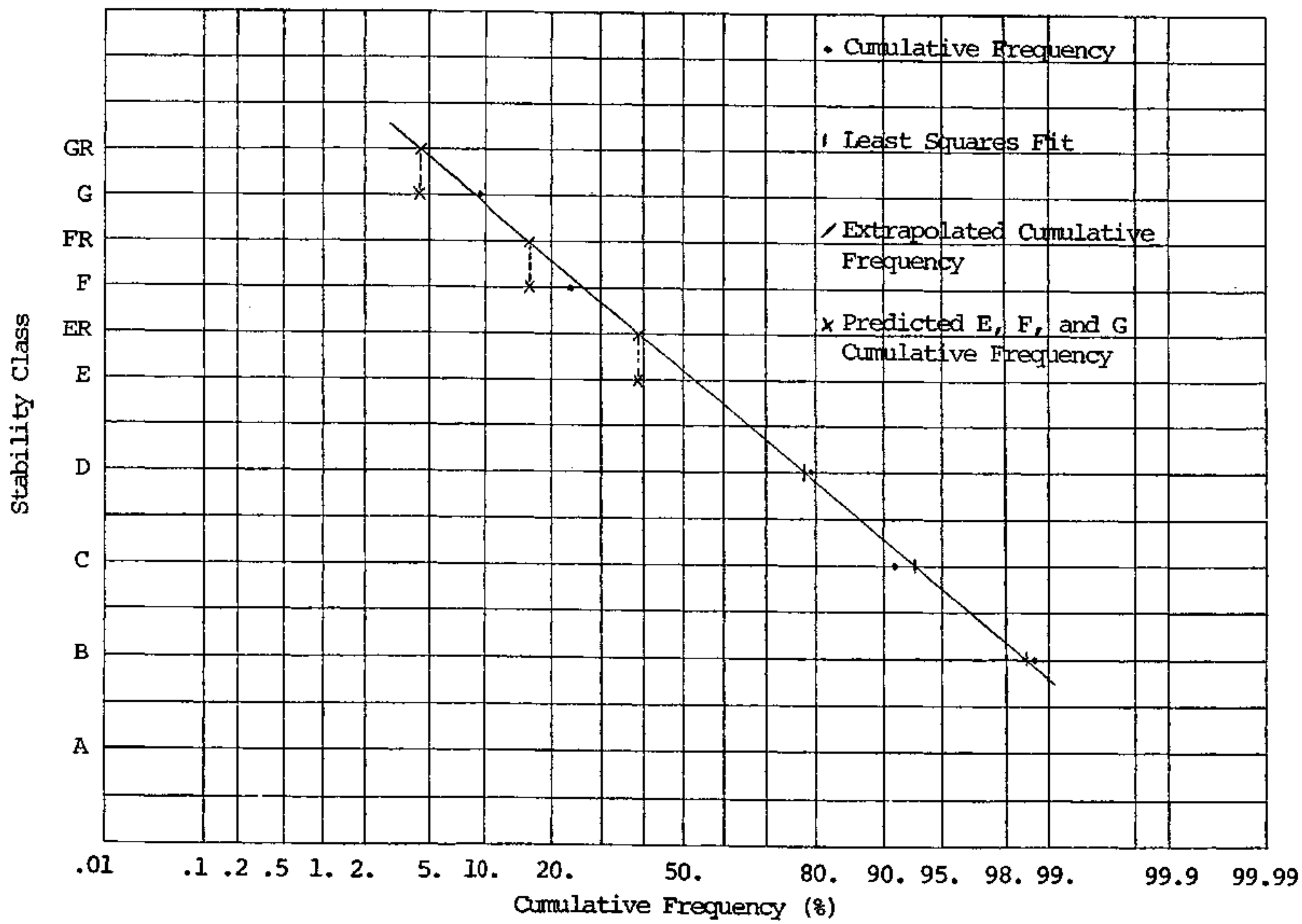


Figure 9. Orlando Cumulative Frequency of Occurrence (G to A).

Table 17. Frequency of Occurrence of Stabilities A through G

Tampa		Tallahassee	
Stability	Frequency	Stability	Frequency
A	0.3493	A	1.2511
B	3.9613	B	7.5091
C	12.7286	C	12.5708
D	51.2637	D	40.5343
E	19.9822	E	14.7466
F	10.5048	F	14.5183
G	1.2101	G	8.8699

Orlando	
Stability	Frequency
A	0.9384
B	6.0639
C	13.2260
D	39.8699
E	18.5548
F	16.5365
G	4.8105

through the point ER. This is a valid procedure because the cumulative frequency at ER must remain equal to the original value of E. The y axis is defined as lying along the cumulative frequency and the axis as along the stability. The line through the points B, C, D, ER then must follow the equation:

$$(y - y_E) = A\ (x - x_E) \tag{B-1}$$

where y_E and x_E are the measured coordinates of the point ER and A is the slope. The value for A is determined by the "least squares" method and is given by:

$$A = \frac{\sum_{i=1}^{M} (x_i - x_E)(y_i - y_E)}{\sum_{i=1}^{M} (x_i - x_E)^2} \tag{B-2}$$

Figures 7 through 9 show the discrepancies in frequency of occurrence between the predicted and extrapolated, E, F, and G values. The x notations in the figures indicate the cumulative frequency values predicted by the method. As shown by the figures and noted in the "% Change in Frequency of Occurrence" columns of Tables 18 through 20, the error between actual and calculated values may be significant. However, it is felt that while the method may be inadequate in particular instances, it would prove statistically valid if used for a large number of sites.

Once the cumulative frequency values for FR and GR are

Table 18. Tampa Data

Determined from STAR Output		Determined from Extrapolation Technique	
Cumulative Frequency of Occurrence of Stability Classes		**Cumulative Frequency of Occurrence of Stability Classes**	
E	0.317	ER	0.317
F	0.117	FR	0.084
G	0.012	GR	0.0112
Frequency of Occurrence of Stability Classes		**Frequency of Occurrence of Stability Classes**	
E	0.200	ER	0.233
F	0.105	FR	0.072
G	0.012	GR	0.012

% Change Between Extrapolated and STAR Frequency of Occurrence Values	
E	+ 16.5
F	- 31.4
G	0.0

Table 19. Tallahassee Data

Determined from STAR Output		Determined From Extrapolation Technique	
Cumulative Frequency of Occurrence of Stability Classes		Cumulative Frequency of Occurrence of Stability Classes	
E	0.381	ER	0.381
F	0.234	FR	0.152
G	0.089	GR	0.040
Frequency of Occurrence of Stability Classes		Frequency of Occurrence of Stability of Classes	
E	0.147	ER	0.229
F	0.145	FR	0.112
G	0.089	GR	0.040

% Change Between Extrapolated and STAR Frequency of Occurrence Values	
E	+ 55.8
F	- 22.8
G	- 55.0

Table 20. Orlando Data

Determined from STAR Output		Determined from Extrapolation Technique	
Cumulative Frequency of Occurrence of Stability Classes		Cumulative Frequency of Occurrence of Stability Classes	
E	0.399	ER	0.399
F	0.213	FR	0.162
G	0.048	GR	0.045
Frequency of Occurrence of Stability Classes		Frequency of Occurrence of Stability Classes	
E	0.186	ER	0.237
F	0.165	FR	0.117
G	0.048	G	0.045

% Change Between Extrapolated and STAR Frequency of Occurrence Values	
E	+ 27.4
F	- 29.1
G	- 6.2

determined, the frequency of occurrence values may be computed by subtracting GR from FR and FR from ER to obtain FR and ER respectively. These values are included in Tables 18 through 20.

The same technical approach may be applied to a six stability STAR output. The same computation procedures apply. The only difference being that the "least squares fit" line is now derived from the points B, C, D, E, FR.

The only problem remaining is that of assigning an average wind speed corresponding to each stability class. STAR determines an average wind speed with each stability distribution. Since the additional stability frequencies are extrapolated, however, the average wind speed cannot also be extrapolated. For the purposes of this thesis, the average wind speeds under E, F, and G stabilities were defined as 6.5, 4.2, and 1.5 knots respectively. The E and F values were arrived at as an average of the observed values for three available seven stability frequency distributions from STAR. Since G stability occurs only with winds between 0 and 3 knots, average wind speed under G was taken as 1.5 knots.

Computer Technique

The included computer program, F and G stabilities by Least Squares Fit (FGLEST), may be used to derive the frequencies of E, F, and G stabilities as discussed in the extrapolation technique. If the STAR output has five stabilities the frequency of occurrence of E, F, and G can be obtained; if the STAR output has six stabilities, then the values for just F and G can be computed.

The program requires as input only the number of stabilities in the STAR output, the relative frequency of occurrence of these stability classes, and the site location. The output consists of the "least squares fit" values through the points B, C, D, ER or B, C, D, E, FR, and their corresponding stability values. By plotting these on probability graph paper, the extrapolated cumulative frequency values as shown in Figures 7 through 9 can be derived.

The input is all in NAMELIST format. A description of NAMELIST use and characteristics may be found in most computer manuals. The input parameters are introduced under the data set $INDATA. The following is a listing of the FGLEST input and an explanation of the input variables:

FGLEST Input

$INDATA

N = the number of relative frequency values which will be inputted; N will be either five or six depending on the STAR output being expanded

RELFRQ = x_1, through x_5 or x_6

the relative frequency of occurrence of the N stability classes; these should be in decimal form and in the order A through E or F

ISITE = the weather station supplying the wind data; this may consist of 18 characters written as three six letter words in Hollerith format

Conclusions

As seen in Tables 18 through 20, the frequency of occurrence values may increase or decrease by large amounts. It must be remembered, however, that whenever this technique is employed it should be employed only as a first estimate. The overall change in frequency of occurrence would indicate that the method could be used for first estimates of pollution concentrations or for other studies where an immediate rough approximation is needed.

Calculation of an annual seven stability distribution was used only as an example in this thesis. The method may also be employed, using the same techniques to obtain seasonal, monthly, or other time period seven stability distributions.

For Tampa, Tallahassee, and Orlando, the method appears valid for crude approximations. This would imply that for other Florida locations or areas of similar meteorological and topographical characteristics the technique could be employed. However, caution should be employed for sites differing from these characteristics. Similar studies should be performed for areas of different topographical and climatic conditions; for example, the northern Southeast, the Midwest, and the Plains.

The technique will be employed in this thesis because of the high cost of obtaining seven stability distributions for local stations near the six selected nuclear stations. However, cost is relevant to the case in hand. When doing a site selection for a nuclear power plant, the expense of \$200 for wind data would be insignificant. The technique would be utilized only if time were an important factor.

A listing of FGLEST, a sample input and output for River Bend Nuclear Station are on subsequent pages.

Program FGLEST

MAIN PROGRAM

```
C  THIS FROGRAM CALCULATES THE LEAST SQUARES FIT VALUES
     .  FOR B THROUGH E
C  STABILITIES.THE FOLLOWING IS A LIST OF VARIABLES USED
C  N  NUMBER OF STABILITIES INPUTTED
C   RELFRQ  RELATIVE FREQUENCY OF OCCURRENCE OF A THROUGH
     .  "N" STABILITIES
C  ISITE IS THE STATION FROM THE WHICH THE WIND DATA
     .  CAME.IT IS INPUTTED IN
C  NAMELIST FORMAT .FOR EXAMPLE   TALLAHASSEE WOULD BE
     .  INPUTTED IN THE
C  FOLLOWING MANNER
C  ISITE=6HTALLAH,5HASSEE
C   INDATA  VARIABLE DATA WHICH WILL CHANGE WITH EACH SITE
C   CUMFRQ  CUMULATIVE FREQUENCY OF OCCURRENCE FOR
     .  STABILITIES "N" THRU A
C  ISTAB  STABILITY CLASS NUMBER A THRU "N" = 1 THRU "N"
C  JSTAB  STABILITY CLASS NUMBER B THRU "N" = 2 THRU "N"
C  XINCR  = OF INCHES IN 10 DIVISIONS ALONG THE X AXIS
C  YT  TEMPORY ARRAY FOR STORING Y DISTANCE VALUES
C  X  THE DISTANCE OUT ON THE X AXIS FOR EACH STABILITY
C  Y  THE DISTANCE OUT ON THE Y AXIS FOR EACH STABILITY
C  M= N - 1 STABILITIES.  FOR 100.00 PERCENT CUM. FREQ.
     .  THERE IS NO POINT
C  ON THE GRAPH AND THEREFORE 1 LESS STABILITY IS NEEDED
C  A  SLOPE OF THE LINE THROUGH THE POINTS B,C,D,"N"
C  RNUM NUMERATOR OF A FOR EACH STABILITY CLASS
C  RNUMTL  TOTAL NUMERATOR OF A
C  DEN  DENOMINATOR OF A FOR EACH STABILITY CLASS
C  DENTL  TOTAL DENOMINATOR OF A
C  YFIT  LEAST SQUARES VALUES FOR THE POINTS B,C,D,"N"
C  I  ARRAY NUMBER
C  YINCH THE NUMNER OF INCHES PER CUMULATIVE FREQUENCY
C  YCUM THE CUMULATIVE FREQUENCY PER NUMBER OF INCHES
C  IADD THE NUMBER OF ADDITIONAL CALCULATED VALUES IN YINCH
     .  + YCUM
C  MINUS THE NUMBER OF UNITS TO SUBTRACT IN ORDER TO ADD
     .  THE RIGHT NUMBER
C  OF UNITS TO YINCH AND YCUM
C ICHECK ARRAY LOCATION THAT CUMFRQ IS CHECKED AGAINST TO
     .  DETERMINE ITS
C  LOCATION ON THE  Y AXIS
C  PFITY   YFIT VALUES CONVERTED FROM INCHES TO PERCENT
C  STB A THROUGH G  STABILITY TO BE PLOTTED ON THE GRAPH
C K=M-1  THIS IS THE NUMBER OF POINTS FOR WHICH A LEAST
     .  SQUARES VALUE OF Y
```

MAIN PROGRAM

```
C   WILL BE CALCULATED
C   UNITX  NUMBER OF STANDARD DIVISIONS PER STABILITY ON THE
     .  X AXIS
      DIMENSION RELFRQ(6),CUMFRQ(6),X(6),Y(6),YT(6),YFIT(5),
     .  YINCH(115),YCUM(115),PFITY(5),STB(7),UNITX(7)
      DATA UNITX/10,20,30,40,55,65,75/
      DATA STB/"A","B","C","D","E","F","G"/
      DATA CUMFRQ/6*0.000000/
      DATA YCUM/0.0100 , 0.0200 , 0.0300 , 0.0400 , 0.0500 ,
     .            .0600 ,   .0700 ,   .0800 ,   .0900 ,
     .      .1000 ,
     .            .1500 ,   .2000 ,   .3000 ,   .4000 ,
     .      .5000 ,
     .            .6000 ,   .7000 ,   .8000 ,   .9000 ,
     .     1.0000 ,
     .           1.2000 ,  1.4000 ,  1.6000 ,  1.8000 ,
     .     2.0000 ,
     .           3.0000 ,  4.0000 ,  5.0000 ,  6.0000 ,
     .     7.0000 ,
     .           8.0000 ,  9.0000 , 10.0000 , 11.0000 ,
     .    12.0000 ,
     .          13.0000 , 14.0000 , 15.0000 , 16.0000 ,
     .    17.0000 ,
     .          18.0000 , 19.0000 , 20.0000 , 22.0000 ,
     .    24.0000 ,
     .          26.0000 , 28.0000 , 30.0000 , 32.0000 ,
     .    34.0000 ,
     .          36.0000 , 38.0000 , 40.0000 , 42.0000 ,
     .    44.0000 ,
     .          46.0000 , 48.0000 , 50.0000 , 57*0.0000/
      DATA YINCH/ .00000 ,  .23333 ,  .36667 ,  .46667 ,
     .     .54167 ,
     .            .60833 ,  .66667 ,  .71667 ,  .75833 ,
     .     .79167 ,
     .            .94167 , 1.05000 , 1.22083 , 1.34167 ,
     .    1.43333 ,
     .          1.50833 , 1.58333 , 1.64167 , 1.70000 ,
     .    1.75000 ,
     .          1.83333 , 1.90833 , 1.97500 , 2.03333 ,
     .    2.08750 ,
     .          2.30000 , 2.46667 , 2.59167 , 2.70417 ,
     .    2.80833 ,
     .          2.89167 , 2.97500 , 3.05000 , 3.11667 ,
     .    3.18333 ,
```

MAIN PROGRAM

```
     .              3.24167 , 3.30000 , 3.35000 , 3.40833 ,
     .      3.45833 ,
     .              3.50000 , 3.55417 , 3.60000 , 3.68333 ,
     .      3.76667 ,
     .              3.84167 , 3.91667 , 3.99167 , 4.06667 ,
     .      4.13333 ,
     .              4.20000 , 4.26667 , 4.32917 , 4.39167 ,
     .      4.45833 ,
     .              4.52083 , 4.58750 , 4.64167 , 57*0.00000/
      DIMENSION ISITE(3)/18H                                 /
      NAMELIST/INDATA/N,RELFRQ,ISITE
      READ(5,INDATA)
      RNUMTL=0.00000
      DENTL=0.00000
      XINCR=0.744666667
      M=N-1
      NN=N+1
C   CALCULATE REVERSE CUM FREQ OF OCCURRENCE "N" THRU A
      DO 5 ISTAB=1,N
      RELFRQ(ISTAB)=RELFRQ(ISTAB)* 100.0000
    5 CONTINUE
      CUMFRQ(1)=RELFRQ(N)
      DO 10 ISTAB=2,N
      CUMFRQ(ISTAB) = (CUMFRQ(ISTAB - 1) + RELFRQ(NN -
     .  ISTAB))
   10 CONTINUE
C   CALCULATE X VALUES FOR LEAST SQUARES FIT
      DO 30 ISTAB= 1,N
      IF(ISTAB.GE.5)  GO TO 20
      X(ISTAB) = XINCR * ISTAB
      GO TO 30
   20 X(ISTAB) = XINCR * ISTAB + .5 * XINCR
   30 CONTINUE
C   CALCULATE THE TOTAL DISTANCE TO THE END OF THE Y AXIS +
     .  TOTAL CUM  PERCENT
      DO 40 IADD = 59,115
      YINCH(IADD) = 2* YINCH(58) - YINCH(116-IADD)
      YCUM(IADD) = 2 * YCUM(58) - YCUM(116-IADD)
   40 CONTINUE
C   CALCULATE THE Y VALUES CORRESPONDING TO THE CUM FREQ
     .  VALUES. THE ORDER OF
C    THIS ARRAY MUST LATER BE CHANGED  BEFORE CALCULATING
     .  THE LEAST SQUARE VALUES
      DO 60 ISTAB = 1,M
      DO 59 ICHECK = 1,115
```

MAIN PROGRAM

```
      IF(CUMFRQ(ISTAB).GT.YCUM(ICHECK)) GO TO 59
      IF(CUMFRQ(ISTAB)-YCUM(ICHECK - 1))  55,50,57
C  IF THE CUM FREQ OF THE DATA IS NOT EXACTLY EQUAL TO THE
     .  CUM FREQ VALUES OF
C  THE GRAPH PAPER  THEN DO A LINEAR INTERPOLATION  BETWEEN
     .  THE 2 CLOSEST
C  VALUES OF THE GRAPH PAPER
   57 YT(ISTAB)=(CUMFRQ(ISTAB) - YCUM(ICHECK - 1))/
     .  (YCUM(ICHECK) - YCUM(ICHECK - 1))
      YT(ISTAB) = YT(ISTAB) * (YINCH(ICHECK) - YINCH(ICHECK
     .  - 1))
     .  + YINCH(ICHECK - 1)
      GO TO 60
   50 YT(ISTAB) = YINCH(ICHECK)
      GO TO 60
   55 WRITE(6,56) ISTAB,ICHECK,CUMFRQ(ISTAB),YCUM(ICHECK-1)
   56 FORMAT(4X,"ISTAB=",I1,/,4X,"ICHECK=",I3,/,4X,
     .  "CUMFRQ=",F8.4,/,
     . 4X,"YCUM=",E7.5)
      GO TO 330
   59 CONTINUE
   60 CONTINUE
C  REVERSE THE ORDER OF THE Y VALUES SO THE LEAST SQUARES
     .  USES THE POINTS
C  X(1),Y(1),X(2),Y(2), ETC. INSTEAD OF X(1),Y(5),X(2),Y(4)
      DO 70 ISTAB = 1,M
      Y(ISTAB)=YT(N - ISTAB)
   70 CONTINUE
C  CALCULATE A
      DO 80 JSTAB = 2,N
      KSTAB=JSTAB - 1
      RNUM = (X(JSTAB ) - X(N)) * (Y(KSTAB) - Y(M))
      RNUMTL = RNUMTL + RNUM
      DEN = (X(JSTAB) - X(N))** 2
      DENTL = DENTL + DEN
   80 CONTINUE
      A = RNUMTL/DENTL
      K = M - 1
C  CALCULATE LEAST SQUARES VALUES FOR Y AT POINTS B,C,D,
     .   + E(IF INPUTTING 6 STAB
      YFIT(M) = Y(M)
      DO 90 JSTAB = 2,N
      KSTAB=JSTAB - 1
      YFIT(KSTAB) = A * (X(JSTAB) - X(N)) + Y(M)
   90 CONTINUE
```

MAIN PROGRAM

```
C  CONVERT LEAST SQUARES VALUES OF Y TC PERCENTAGES
      DO 140 I=1,M
      DO 135 ICHECK = 1,115
      IF(YFIT(I).GT.YINCH(ICHECK)) GO TO 135
      IF(YFIT(1) - YINCH(ICHECK -1)) 100,130,120
  100 WRITE(6,110) I,ICHECK,YFIT(I),YINCH(ICHECK)
  110 FORMAT(4X,"I=",I1,4X,"ICHECK=",I3,4X,"YFIT(I)=",F8.5,
     .  4X,"YINCH(IC
     .HECK)=",F8.5)
      GO TO 330
  120 PFITY(1) = (YFIT(I) - YINCH(ICHECK - 1))/(YI
     .  NCH(ICHECK) -
     .  YINCH(ICHECK - 1))
      PFITY(I) = PFITY(I) * (YCUM(ICHECK) - YCUM(ICHECK -
     .  1)) +
     .   YCUM(ICHECK - 1)
      GO TO 14C
  130 PFITY(I) = YCUM(ICHECK)
  135 CONTINUE
  140 CONTINUE
C  PRINT ALL NEEDED VALUES TO GRAPH
      WRITE(6,154)
  154 FORMAT(1H1)
      WRITE(6,145)  (ISITE(K),K=1,3)
  145 FORMAT(1X,"STATICN = ",3A6,///)
      WRITE(6,150)
  150 FORMAT(1X,"THE FCLLOWING VALUES CF STABILITY AND
     .  CUMULATIVE PERCEN
     .T ARE TO BE PLOTTED ON",/)
      WRITE(6,160)
  160 FORMAT(17X," *** K + E ,KEUFFEL + ESSER CO ,
     .     46 8000***")
      WRITE(6,170)
  170 FORMAT(17X," ***PROBABILITY X 90 DIVISION GRAPH PAPER
     .  **",/)
      WRITE(6,180)
  180 FORMAT(2X,"THE X AXIS IS DEFINED AS THE 90 DIVISION
     .  AXIS.")
      WRITE(6,185)
  185 FORMAT(2X,"THE Y AXIS IS DEFINED AS THE PROBABILITY
     .  AXIS.")
      WRITE(6,186)
  186 FORMAT(2X,"THE STABILITY VALUES ARE PLOTTED ALONG THE
     .  X AXIS.",/,
     .  2X,"THE CUMULATIVE PERCENT VALLES ARE PLOTTED ALONG
     .  THE Y AXIS."
```

MAIN PROGRAM

```
     .,///)
      WRITE(6,190)
  190 FORMAT(5X,"STABILITY",5X,"X VALUES",4X,"CUM FREQ BY")
      WRITE(6,200)
  200 FORMAT(7X,"CLASS",7X,"(UNITS)",6X,"LEAST SQS",/)
      WRITE(6,210) STB(1),UNITX(1)
  210 FORMAT(9X,A1,12X,I2,9X,"100.0000  (OFF THE GRAPH)",/)
      WRITE(6,220) (STB(I),UNITX(I),PFITY(I-1),I=2,N)
  220 FORMAT(9X,A1,12X,I2,10X,F7.4,/)
      IF(N.EQ.6) GO TO 240
      WRITE(6,230) STB(6),UNITX(6)
  230 FORMAT(9X,A1,12X,I2,10X,"EXTRAPOLATED VALUE",/)
  240 WRITE(6,230) STB(7),UNITX(7)
      WRITE(6,270) N
  270 FORMAT(5X,"NUMBER OF STABILITIES INPUTTED = ",I1,///)
      WRITE(6,280)
  280 FORMAT(5X,"STABILITY",5X,"RELATIVE",5X,"CUM FREQ BY")
      WRITE(6,290)
  290 FORMAT(7X,"CLASS",7X,"FREQUENCY",3X,"ACTUAL VALUES",/)
      WRITE(6,300) (STB(I),RELFRQ(I),CUMFRQ( NN - I),I=1,N)
  300 FORMAT(9X,A1,10X,F7.4,6X,F8.4,/)
C WRITE X + Y DISTANCES
      WRITE(6,305)
  305 FORMAT(1H1)
      WRITE(6,310)
  310 FORMAT(///,10X,"X DISTANCE",10X,"Y DISTANCE",/)
      WRITE(6,320) (STB(I),X(I),Y(I-1),I=2,N)
  320 FORMAT(5X,A1,4X,F8.5,12X,F8.5,/)
      WRITE(6,325)
  325 FORMAT(1H1)
  330 STOP
      END
```

SAMPLE INPUT TO FGLEST

```
$INDATA

N = 5

RELFRQ = .014249, .080285, .111248, .387245, .406974

INSITE = 6HBATON, 6HROUGHE, 3HLA


$END
```

SAMPLE OUTPUT FROM FGLEST

STATION = BATON ROUGE LA.

THE FOLLOWING VALUES OF STABILITY AND CUMULATIVE PERCENT ARE TO BE PLOTTED ON

*** K + E (KEUFFEL + ESSER CO , 46 8000***
***PROBABILITY X 90 DIVISION GRAPH PAPER **

THE X AXIS IS DEFINED AS THE 90 DIVISION AXIS.
THE Y AXIS IS DEFINED AS THE PROBABILITY AXIS.
THE STABILITY VALUES ARE PLOTTED ALONG THE X AXIS.
THE CUMULATIVE PERCENT VALUES ARE PLOTTED ALONG THE Y AXIS.

STABILITY CLASS	X VALUES (UNITS)	CUM FREQ BY LEAST SQS
A	10	100.0000 (OFF THE GRAPH)
B	20	98.2803
C	30	92.5613
D	40	78.0826
E	55	40.6974
F	65	EXTRAPOLATED VALUE
G	75	EXTRAPOLATED VALUE

NUMBER OF STABILITIES INPUTTED = 5

STABILITY CLASS	RELATIVE FREQUENCY	CUM FREQ BY ACTUAL VALUES
A	1.4249	100.0001
B	8.0265	98.5752
C	11.1248	90.5467
D	38.7245	79.4219
E	40.6974	40.6974

APPENDIX C

ESTMAT Listing, Sample Input and Sample Output

The following is a listing of the computer program ESTMAT and a sample input and output for River Bend Nuclear Station.

Program ESTMAT

MAIN PROGRAM

```
      REAL NUM
      DIMENSION HEADR1(20),HEADR2(20)
      DIMENSION RELFRQ(7),WS(7),XQ(16,7),CUM(7),STAB(7)
      DIMENSION HT(16),ELEV(16),DIR(16)
      DIMENSION SIGMAY(16,7),SIGMAZ(16,7),DIST(16)
      DATA STAB/"A","B","C","D","E","F","G"/
      DATA DIR/"  N","NNE"," NE","ENE","  E","ESE"," SE",
     . "SSE","  S",
     . "SSW"," SW","WSW","  W","WNW"," NW","NNW"/
      DATA XQ/112*0.0/
      DATA CUM/7*0.0/
      DATA SIGMAY/112*0.0/
      DATA SIGMAZ/112*0.0/
      DATA ELEV/16*0.0/
      PI = 3.141592654
      NAMELIST/INPUT/RELFRQ,WS,HT,PHT,DIST,CA
      READ(5,5) HEADR1
    5 FORMAT(20A4)
      READ(5,5) HEADR2
      READ(5,INPUT)
C   CALCULATE THE ELEVATION AT THE EVUALATION POINT
      DO 6 J=1,16
      ELEV(J)=HT(J) - PHT
    6 CONTINUE
C   CALCULATE THE CUMULATIVE FREQUENCY FROM G THROUGH A
      CUM(1) = RELFRQ(7)
      DO 10 I=2,7
      CUM(I) = CUM(I - 1) + RELFRQ(8 - I)
   10 CONTINUE
      CALL SIGYZ(DIST,SIGMAY,SIGMAZ)
C CONVERT WIND SPEED FROM KNOTS TO M/SEC AND CALCULATE X/Q
      DO 33 I=1,7
      WS(I) = WS(I) * 0.514444
   33 CONTINUE
      DO 21 J=1,16
      DO 20 I = 1 , 7
      NUM=0.0
      DENOM=0.0
      NUM = EXP(- (ELEV(J) ** 2/(2 * (SIGMAZ(J,I) ** 2 ))))
      DENOM = WS(I) * ( PI * SIGMAY(J,I) * SIGMAZ(J,I) + CA)
      XQ(J,I) = NUM / DENOM
   20 CONTINUE
   21 CONTINUE
      WRITE(6,15)
```

MAIN PROGRAM

```
   15 FORMAT(1H1)
      WRITE(6,16)
   16 FORMAT(////)
      WRITE(6,17)  HEADR1
   17 FORMAT(5X,18A4,/)
      WRITE(6,17)  HEADR2
      DO 1050 J=1,16
      IF(J.EQ.1)  GO TO 2001
      IF(MOD(J,2).NE.0)  WRITE(6,16)
 2001 CONTINUE
      WRITE(6,1000) DIR(J),DIST(J),ELEV(J),PHT
 1000 FORMAT(10X,"DIRECTION = ",A3,5X,"DISTANCE = ",F7.1,
     .  "M",5X,
     .  "ELEVATION = ",F7.1,"M",5X,"PLANT HEIGHT = ",F7.1,
     .  "M",/)
      WRITE(6,30)
   30 FORMAT(10X,"STABILITY",8X,"RELATIVE",7X,"CUMULATIVE",
     .  10X," E",16X,
     .  "SIGMA Y",11X,"SIGMA Z")
      WRITE(6,40)
   40 FORMAT(12X,"CLASS",10X,"FREQUENCY",6X,"FREQUENCY",8X,
     .  "(SEC/M**3)",
     .  13X,"(M)",16X,"(M)",/)
      DO 60 I=1,7
      WRITE(6,50) STAB(I),RELFRQ(I),CUM(8 - I),XQ(J,I),
     .  SIGMAY(J,I),
     .  SIGMAZ(J,I)
   50 FORMAT(14X,A1,12X,F7.3,9X,F7.3,7X,E11.4,9X,F10.3,8X,
     .  F10.3,/)
   60 CONTINUE
      WRITE(6,1010)
 1010 FORMAT(1H0)
      IF(MOD(J,2).EQ.0)  WRITE(6,1030)
 1030 FORMAT(1H1)
 1050 CONTINUE
 3000 STOP
      END
```

SUBROUTINE

```
      SUBROUTINE SIGYZ(DIST,SIGMAY,SIGMAZ)
      DIMENSION A(11),B(11),C(11),D(7),E(7)
      DIMENSION DISTKM(16),SIGMAY(16,7),SIGMAZ(16,7),
     .  DIST(16)
      DATA A/.000570  ,  .0471  ,  .108  ,  .103  ,
     .   .0953  ,  .0631  ,
     .   .0399,  .466  ,  1.08  ,  6.81  ,  4.31/
      DATA B/  1.95  , 1.12 ,   .917 , .831 , .788 , .785 ,
     .   .785 , .615,
     .  .473 , .254 , .254/
      DATA C/ 9.59 , 2.73 , .0454 , -.0566 , -.0538 ,
     .   .00392 , .00248 ,
     .  -.547 , -6.40 , -25. , -15.8/
      DATA D/ 215. , 155. , 104. , 69.0 , 50.0 , 32.5 ,
     .   20.6/
      DATA E/.874 , .895 , .917 , .921 , .921 , .921 , .921/
      DO 51 J = 1,16
      DISTKM(J) = DIST(J) / 1000.
      DO 50 I = 1,7
      IF(1000. - DIST(J))  30,20,20
   20 SIGMAZ(J,I) = A(I) * (DIST(J) ** B(I)) + C(I)
      GO TO 45
   30 CONTINUE
      IF(I .GE. 4) GO TO 40
      SIGMAZ(J,I) = A(I) * (DIST(J) **B(I)) + C(I)
      GO TO 45
   40 SIGMAZ(J,I) = A(I + 4) * (DIST(J) ** B(I + 4))+ C(I +
     .  4)
C  CALCULATE SIGMA Y VALUES
   45 SIGMAY(J,I) = D(I) * (DISTKM(J) ** E(I))
   50 CONTINUE
   51 CONTINUE
      RETURN
      END
```

Sample Input to ESTMAT

RIVER BEND NUCLEAR STATION

WIND DATA FROM BATON ROUGE, LA.

```
$INPUT

RELFRQ = 1.4249, 8.0285, 11,1248, 38.7245, 21.9974, 12.8, 5.9

WS = 2.5, 5.3, 7.6, 8.9, 6.5, 4.2, 1.5

HT = 30.9, 32., 33.2, 33., 33.9, 32.6, 31.5, 29.4, 32.4, 30.4,
     33.8, 30.6, 33.1, 32.1, 34.7, 34.7

PHT = 29.

DIST = 693., 640., 640., 610., 579., 549., 533., 526., 526.,
       564., 594., 625., 655., 678., 693

cA = 692.


$END
```

Sample Output from ESTMAT

RIVER BEND NUCLEAR STATION

WIND DATA FROM BATON ROUGE,LA.

DIRECTION = N DISTANCE = 693.0M ELEVATION = 1.9M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.7611E-05	156.041	206.971
B	8.029	98.575	.1371E-04	111.632	74.285
C	11.125	90.547	.2354E-04	74.299	43.534
D	38.725	79.422	.5019E-04	49.223	23.575
E	21.997	40.697	.1172E-03	35.669	16.450
F	12.800	18.700	.3094E-03	23.185	10.719
G	5.900	5.900	.1240E-02	14.695	6.778

DIRECTION = NNE DISTANCE = 640.0M ELEVATION = 3.0M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.9439E-05	145.559	178.605
B	8.029	98.575	.1596E-04	103.959	68.185
C	11.125	90.547	.2692E-04	69.072	40.474
D	38.725	79.422	.5602E-04	45.745	22.063
E	21.997	40.697	.1276E-03	33.148	15.447
F	12.800	18.700	.3223E-03	21.546	10.070
G	5.900	5.900	.1202E-02	13.657	6.368

DIRECTION = NE   DISTANCE = 640.0M   ELEVATION = 4.2M   PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.9437E-05	145.559	178.605
B	8.029	98.575	.1594E-04	103.959	68.185
C	11.125	90.547	.2685E-04	69.072	40.474
D	38.725	79.422	.5553E-04	45.745	22.063
E	21.997	40.697	.1253E-03	33.148	15.447
F	12.800	18.700	.3089E-03	21.546	10.070
G	5.900	5.900	.1080E-02	13.657	6.368

DIRECTION = ENE   DISTANCE = 610.0M   ELEVATION = 4.0M   PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1074E-04	139.578	163.500
B	8.029	98.575	.1747E-04	99.587	64.758
C	11.125	90.547	.2913E-04	66.097	38.733
D	38.725	79.422	.5949E-04	43.766	21.198
E	21.997	40.697	.1327E-03	31.715	14.872
F	12.800	18.700	.3220E-03	20.614	9.698
G	5.900	5.900	.1110E-02	13.066	6.132

DIRECTION = E DISTANCE = 579.0M ELEVATION = 4.9M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1234E-04	133.358	148.617
B	8.029	98.575	.1926E-04	95.045	61.239
C	11.125	90.547	.3168E-04	63.010	36.926
D	38.725	79.422	.6329E-04	41.713	20.296
E	21.997	40.697	.1377E-03	30.227	14.271
F	12.800	18.700	.3181E-03	19.648	9.309
G	5.900	5.900	.9936E-03	12.454	5.887

DIRECTION = ESE DISTANCE = 549.0M ELEVATION = 3.6M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1422E-04	127.299	134.916
B	8.029	98.575	.2133E-04	90.625	57.854
C	11.125	90.547	.3475E-04	60.010	35.170
D	38.725	79.422	.6893E-04	39.719	19.416
E	21.997	40.697	.1497E-03	28.782	13.683
F	12.800	18.700	.3507E-03	18.708	8.929
G	5.900	5.900	.1172E-02	11.858	5.646

DIRECTION = SE   DISTANCE = 533.0M   ELEVATION = 2.5M   PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1538E-04	124.050	127.892
B	8.029	98.575	.2257E-04	88.258	56.058
C	11.125	90.547	.3658E-04	58.404	34.230
D	38.725	79.422	.7236E-04	38.651	18.943
E	21.997	40.697	.1573E-03	28.608	13.366
F	12.800	18.700	.3730E-03	18.205	8.724
G	5.900	5.900	.1311E-02	11.539	5.516

DIRECTION = SSE   DISTANCE = 526.0M   ELEVATION = .4M   PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1593E-04	122.625	124.881
B	8.029	98.575	.2316E-04	87.220	55.274
C	11.125	90.547	.3749E-04	57.700	33.818
D	38.725	79.422	.7429E-04	38.184	18.736
E	21.997	40.697	.1623E-03	27.669	13.227
F	12.800	18.700	.3919E-03	17.985	8.634
G	5.900	5.900	.1456E-02	11.400	5.459

DIRECTION = S DISTANCE = 526.0M ELEVATION = 3.4M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1593E-04	122.625	124.881
B	8.029	98.575	.2311E-04	87.220	55.274
C	11.125	90.547	.3730E-04	57.700	33.818
D	38.725	79.422	.7309E-04	38.184	18.736
E	21.997	40.697	.1571E-03	27.669	13.227
F	12.800	18.700	.3630E-03	17.985	8.634
G	5.900	5.900	.1203E-02	11.400	5.459

DIRECTION = SSW DISTANCE = 526.0M ELEVATION = 1.4M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1593E-04	122.625	124.881
B	8.029	98.575	.2315E-04	87.220	55.274
C	11.125	90.547	.3746E-04	57.700	33.818
D	38.725	79.422	.7410E-04	38.184	18.736
E	21.997	40.697	.1615E-03	27.669	13.227
F	12.800	18.700	.3872E-03	17.985	8.634
G	5.900	5.900	.1413E-02	11.400	5.459

DIRECTION = SW DISTANCE = 564.0M ELEVATION = 4.8M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1324E-04	130.334	141.680
B	8.029	98.575	.2024E-04	92.838	59.544
C	11.125	90.547	.3310E-04	61.511	36.049
D	38.725	79.422	.6563E-04	40.717	19.857
E	21.997	40.697	.1418E-03	29.505	13.978
F	12.800	18.700	.3246E-03	19.178	9.119
G	5.900	5.900	.1005E-02	12.156	5.767

DIRECTION = WSW DISTANCE = 594.0M ELEVATION = 1.6M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1153E-04	136.373	155.726
B	8.029	98.575	.1841E-04	97.246	62.939
C	11.125	90.547	.3059E-04	64.505	37.801
D	38.725	79.422	.6269E-04	42.708	20.733
E	21.997	40.697	.1410E-03	30.948	14.562
F	12.800	18.700	.3531E-03	20.116	9.498
G	5.900	5.900	.1341E-02	12.750	6.006

DIRECTION = W DISTANCE = 625.0M ELEVATION = 4.1M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.1006E-04	142.573	170.967
B	8.029	98.575	.1668E-04	101.776	66.469
C	11.125	90.547	.2795E-04	67.586	39.604
D	38.725	79.422	.5746E-04	44.756	21.631
E	21.997	40.697	.1289E-03	32.432	15.160
F	12.800	18.700	.3154E-03	21.081	9.885
G	5.900	5.900	.1095E-02	13.362	6.250

DIRECTION = WNW DISTANCE = 655.0M ELEVATION = 3.1M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.8867E-05	148.537	186.416
B	8.029	98.575	.1527E-04	106.137	69.906
C	11.125	90.547	.2588E-04	70.555	41.342
D	38.725	79.422	.5417E-04	46.731	22.493
E	21.997	40.697	.1240E-03	33.863	15.733
F	12.800	18.700	.3156E-03	22.011	10.255
G	5.900	5.900	.1184E-02	13.952	6.485

DIRECTION = NW DISTANCE = 678.0M ELEVATION = 5.7M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.8074E-05	153.085	198.725
B	8.029	98.575	.1426E-04	109.467	72.553
C	11.125	90.547	.2425E-04	72.823	42.670
D	38.725	79.422	.5045E-04	48.240	23.149
E	21.997	40.697	.1139E-03	34.957	16.168
F	12.800	18.700	.2769E-03	22.722	10.537
G	5.900	5.900	.9047E-03	14.402	6.663

DIRECTION = NNW DISTANCE = 693.0M ELEVATION = 5.7M PLANT HEIGHT = 29.0M

STABILITY CLASS	RELATIVE FREQUENCY	CUMULATIVE FREQUENCY	E (SEC/M**3)	SIGMA Y (M)	SIGMA Z (M)
A	1.429	100.004	.7609E-05	156.041	206.971
B	8.029	98.575	.1367E-04	111.632	74.285
C	11.125	90.547	.2336E-04	74.299	43.534
D	38.725	79.422	.4890E-04	49.223	23.575
E	21.997	40.697	.1111E-03	35.669	16.450
F	12.800	18.700	.2728E-03	23.185	10.719
G	5.900	5.900	.9055E-03	14.695	6.778

APPENDIX D

DATA

Tables 21 and 22 list the distance to the EZ and elevation at the EZ for each of the six stations.

Of the six plants, only DPNGS had a local seven stability STAR output. The other five stations had either a five or six stability distribution available through NOAA. Table 23 lists the local meteorological station for each of the six plants. Figures 10 through 14 are the graphs determining the frequency of occurrence of F and G stability for each site.

Table 21. Elevation above Mean Sea Level at the EZ Boundary for each Station**

Nuclear Stations

Sector	CPSES	RBS	DPNGS	GEC	ACNGS	SPS
N	256.4	30.9	*17.56	229.0	39.0	5.18
NNE	241.4	32.0	25.40	226.7	39.0	6.10
NE	244.1	33.2	24.02	229.0	39.0	5.71
ENE	241.4	33.0	26.33	226.7	39.0	10.45
E	241.4	33.9	23.56	226.7	39.0	9.14
ESE	201.6	32.6	18.93	226.3	39.0	9.14
SE	242.9	31.5	21.70	230.4	39.0	10.88
SSE	259.4	*29.4	19.39	230.4	41.6	11.22
S	241.4	32.4	5.07	233.7	*44.5	11.22
SSW	251.9	30.4	0.00	233.7	45.5	*11.76
SW	255.4	33.8	0.00	233.7	44.5	11.22
WSW	*248.9	30.6	0.00	233.7	45.3	11.77
W	268.4	33.1	0.00	233.7	44.9	10.2
WNW	247.4	32.1	0.00	232.5	45.5	9.54
NW	241.4	34.7	0.00	*229.0	44.2	6.52
NNW	241.4	34.7	9.23	229.0	43.6	8.99

* Elevation at which the maximum 5%E occurred

** All elevations in meters

Table 22. Distance to EZ Boundary for Each Sector for Each Station**

Nuclear Stations

Sector	CPSES	RBS	DPNGS	GEC	ACNGS	SPS
N	2188.2	693.0	*1006.0	1300.0	1460.0	503.0
NNE	2413.5	640.0	1192.0	1300.0	1448.0	503.0
NE	2461.8	640.0	1576.0	1300.0	1500.0	503.0
ENE	2510.0	610.0	1573.0	1300.0	2121.0	503.0
E	2510.0	579.0	1661.0	1300.0	2129.0	503.0
ESE	2188.2	549.0	1789.0	1300.0	1676.0	503.0
SE	2107.8	533.0	1533.0	1300.0	1372.0	503.0
SSE	2188.2	*526.0	1396.0	1300.0	1323.0	503.0
S	2011.3	526.0	1341.0	1300.0	*1335.0	503.0
SSW	1657.3	526.0	3140.0	1300.0	1524.0	*503.0
SW	1509.2	574.0	6250.0	1300.0	1455.0	503.0
WSW	*1417.5	594.0	5731.0	1300.0	1455.0	503.0
W	1850.4	625.0	5701.0	1300.0	1593.0	503.0
WNW	2220.4	655.0	5914.0	1300.0	2115.0	503.0
NW	2043.4	678.0	978.0	*1300.0	2188.0	503.0
NNW	2027.3	693.0	978.0	1300.0	1669.0	503.0

* Distance at which maximum 5%E occurred

** All distances in meters

Table 23. Nuclear Plants and Their Local Meteorological Stations

Nuclear Station	Meteorological Station	Years of Record	Number of Stability Classes
CPSES	Dallas, Texas	1/67-12/71	6
RBS	Baton Rouge, Louisiana	1/66-12/70	5
DPNGS	Quantico, Virginia/MACS	1/65-12/69	7
GEC	Flint, Michigan	1/65-12/69	6
ACNGS	Houston, Texas	1/64-12/68	6
SPS	Norfolk, Virginia/NAS	12/66-11/71	5

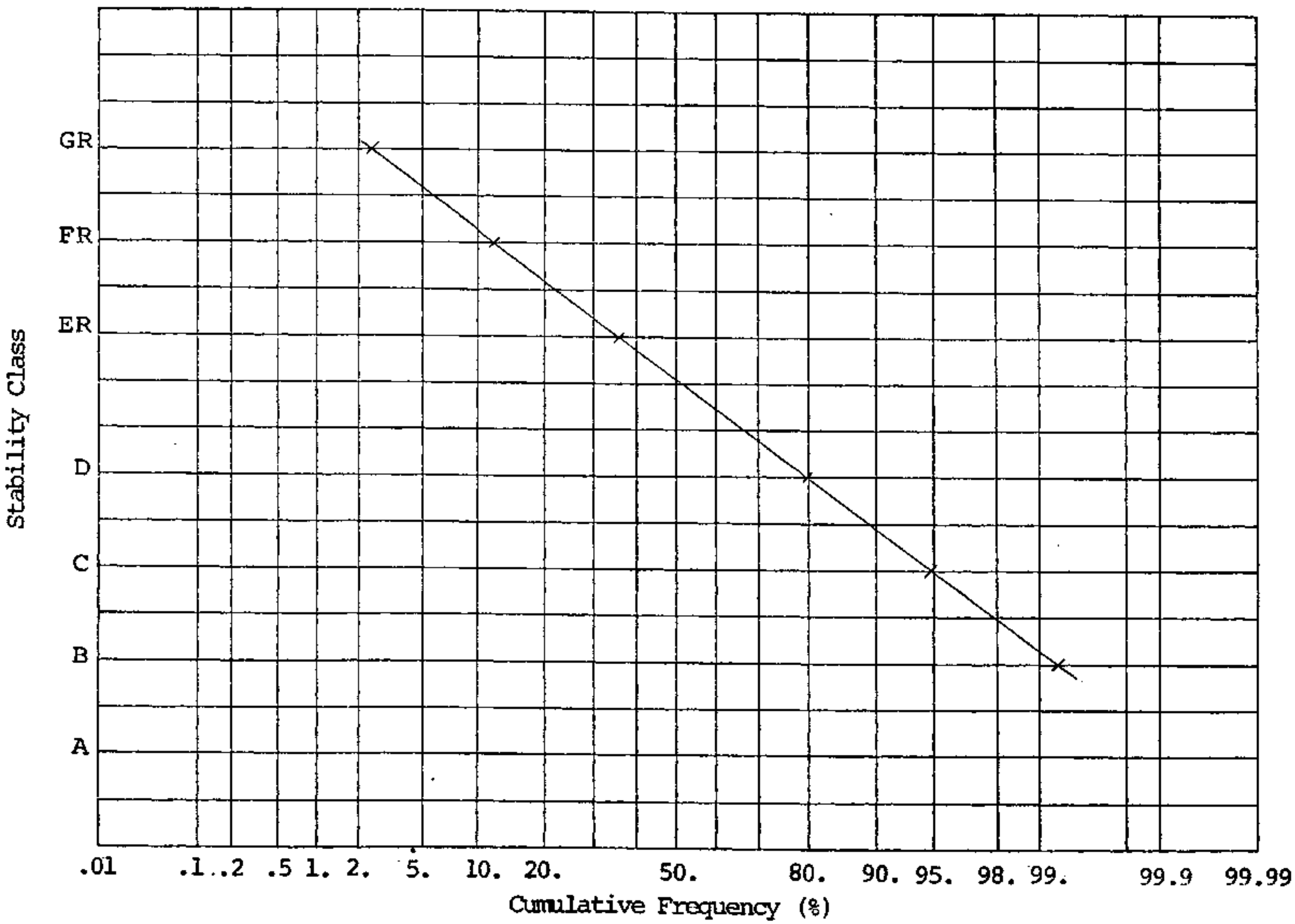


Figure 10. Dallas Cumulative Frequency of Occurrence (G to A).

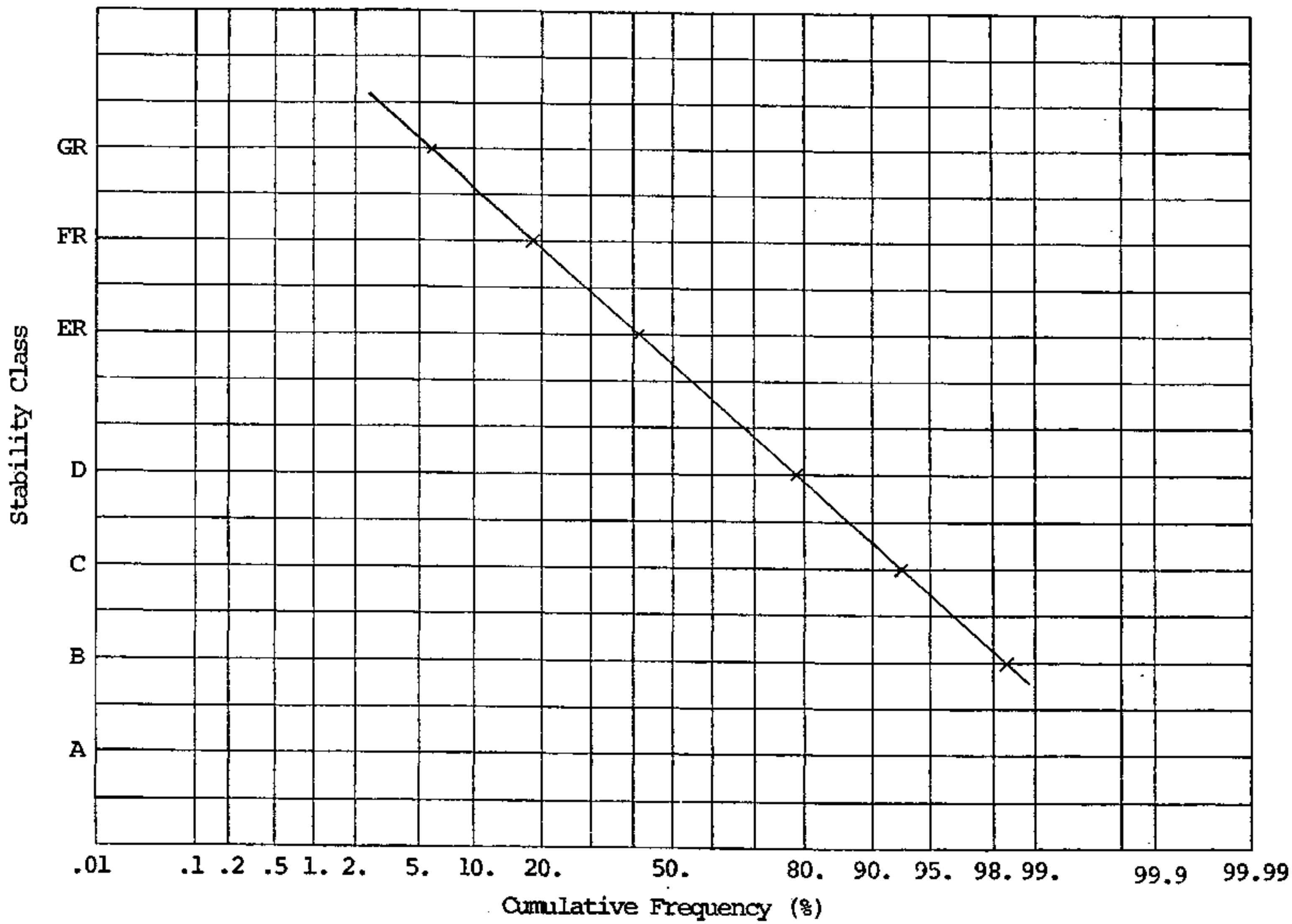


Figure 11. Baton Rouge Cumulative Frequency of Occurrence (G to A).

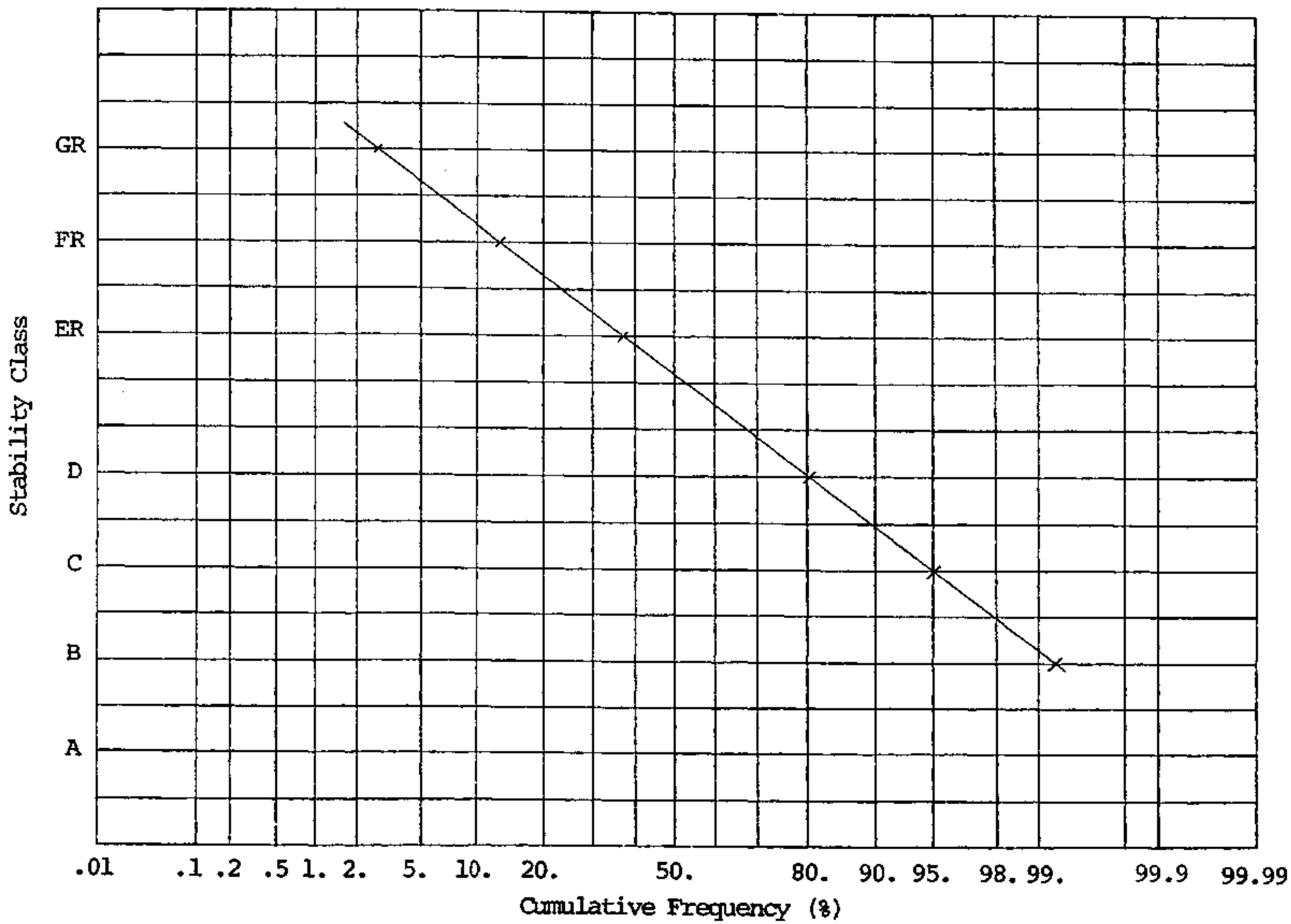


Figure 12. Flint Cumulative Frequency of Occurrence (G to A).

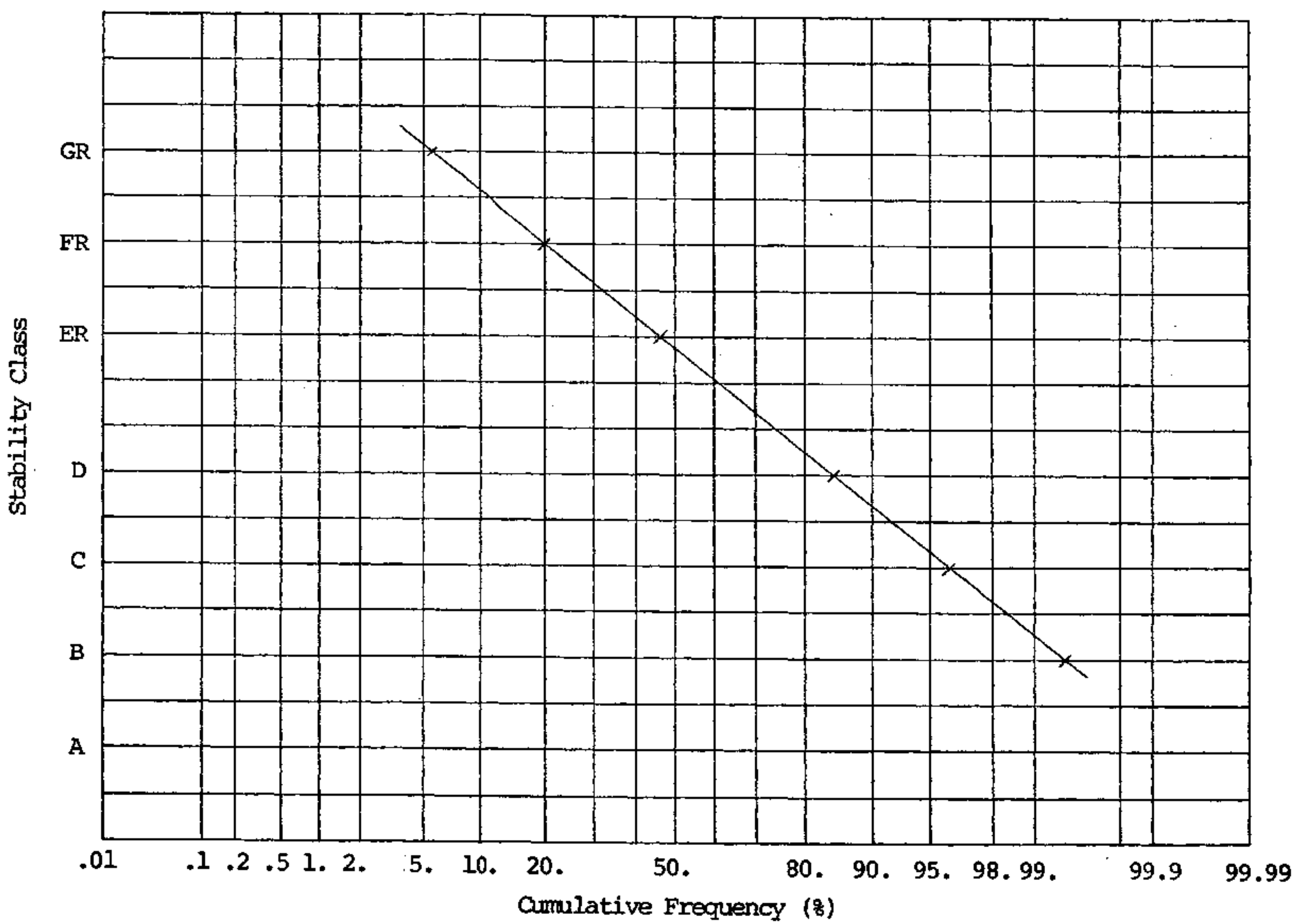


Figure 13. Houston Cumulative Frequency of Occurrence (G to A).

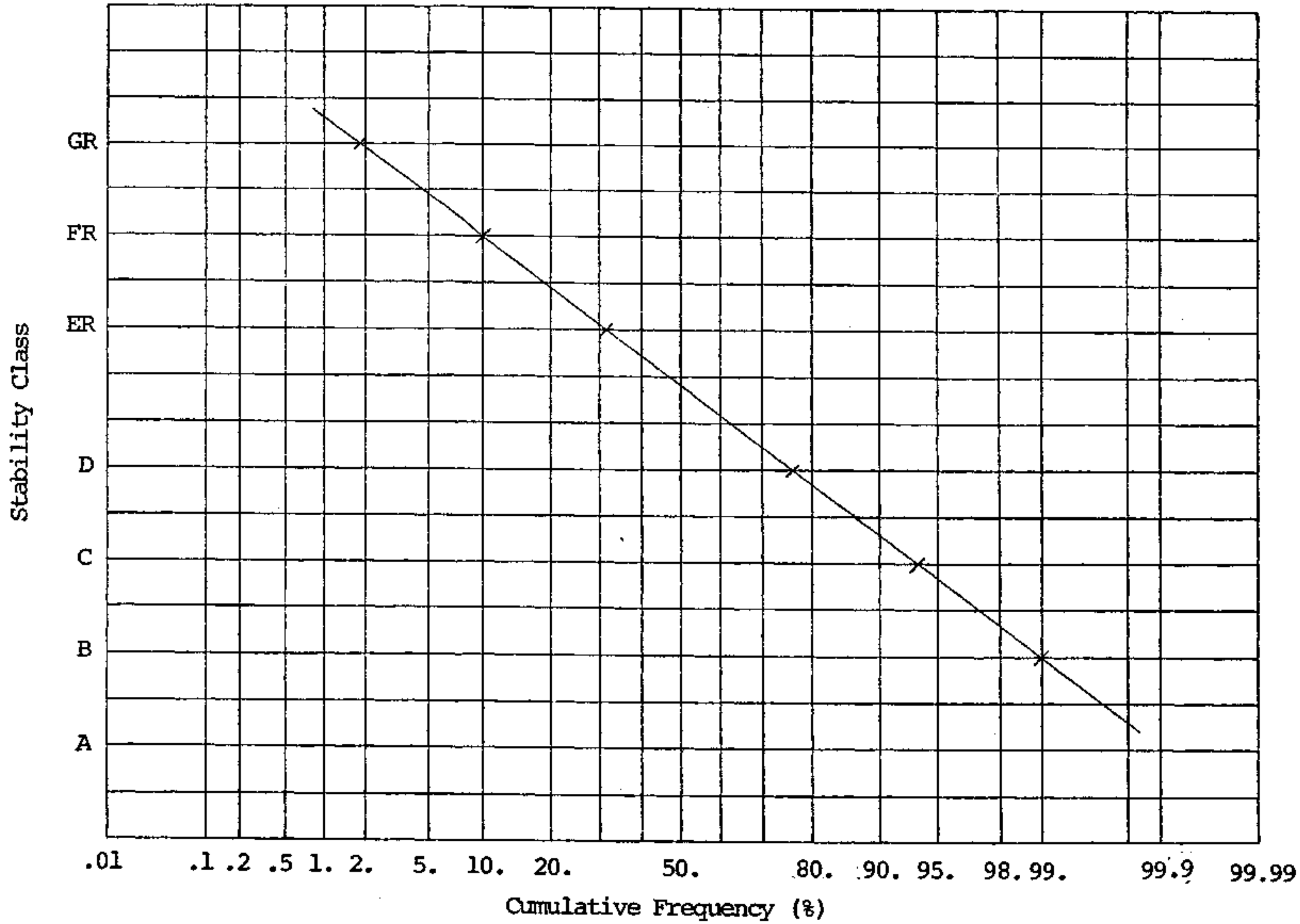


Figure 14. Norfolk Cumulative Frequency of Occurrence (G to A).

APPENDIX E

GLOSSARY

ABBREVIATIONS

ACNGS - Allens Creek Nuclear Generating Station

ALAP - as low as practicable

CPSES - Comanche Peak Steam Electric Station

DPNGS - Douglas Point Nuclear Generating Station

ESTMAT - computer program estimate

EZ - exclusion zone

FGLEST - computer program F and G Stabilities by Least Squares Fit

GEC - Greenwood Energy Complex

km - kilometer

KWe - kilowatts electric

LPZ - low population zone

m - meters

NOAA - National Oceanic and Atmospheric Administration

NRC - National Regulatory Commission

PSAR - Preliminary Safety Analysis Report

RBS - River Bend Station

SAR - Safety Analysis Report

SPS - Surry Power Station

STAR - computer program Stability Rose

U.S. - United States

DEFINITIONS

ALAP - refers to the criterion that radioactivity releases to the environment be as low as is practicably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety and to the utilization of atomic energy in the public interest.

dose - the quantity of radiation absorbed

exclusion zone - that area surrounding the reactor in which the reactor liscensee has the authority to determine all activities including exclusion or removal of personnel and property from the area; this is a physical area usually determined by a fence around the outer boundary.

low population zone - the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident; the actual boundary of this area is not physical.

population center distance - the distance from the reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents.

rem - a measure of the energy deposited in human tissue by ionizing radiation of any sort that enters the tissue.

<u>10 CFR 100</u> - a NRC regulation which provides guidance in the evaluation of the suitability of proposed sites for stationary power and testing reactors.

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